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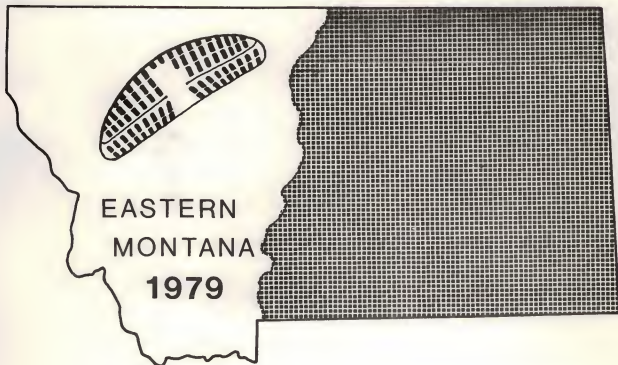
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BIOLOGICAL WATER QUALITY MONITORING

EASTERN MONTANA

1979

by

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June 1981

State of Montana
Water Quality Bureau
Environmental Sciences Division
Department of Health and Environmental Sciences
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Peggy Bahls computed statistics for periphyton community structure. Carla Anderson was the report typist.

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DISCLAIMER

Mention of trade names or commercial products does not constitute endorsement or recommendation for use. This report has been reviewed by the Montana Operations Office, U.S. Environmental Protection Agency, and approved for publication.



ABSTRACT

Values for 33 biologically-related water quality variables were measured seasonally at 36 stations on 21 major streams in eastern Montana from March to October 1979. Streams in eastern Montana have a varied ionic makeup, averaging a bit more sodium than calcium or magnesium and about twice as much sulfate as bicarbonate. Armell's Creek and the Redwater River are high salinity, high sodium waters and are not suitable for irrigation under ordinary conditions. All waters measured are "moderately hard" to "very hard" and would be relatively insensitive to heavy metals contamination. They also give a neutral to alkaline reaction and are well buffered, indicating they would be resistant to acid rainfall and acid-mine drainage. Just four of the streams were clearly phosphorus limited although most streams tended toward phosphorus limitation from spring to fall. Several stations had mean values for both nitrogen and phosphorus in excess of recommended instream concentrations; however, periphyton production is low and nuisance algae growths are uncommon because of the typically turbid waters and unstable bottoms. The Judith River at Danvers had the highest average in situ production rates for chlorophyll and biomass. Most of the phosphate in eastern Montana waters is associated with the nonfiltrable fraction, explaining the meager growth during the algal assay experiments. Only the Yellowstone River below Yeagen Drain in Billings recorded an un-ionized ammonia level in excess of the criterion to protect freshwater aquatic life. Golden-brown, green and blue-green algae dominated the periphyton associations of eastern Montana streams. Diatoms occurred in all samples and ranked number one in 40 percent of those samples; the green alga *Cladophora* occurred in 64

percent of the samples and ranked number one in 35 percent. Only the Judith River at Danvers and three additional sites had mean diatom diversity values that would indicate borderline water quality conditions. Stoneflies, mayflies, caddisflies, true flies and true bugs were the major aquatic insect groups encountered in eastern Montana streams. Sampling problems precluded the collection of a statistically reliable number of organisms at several stations. Macro-invertebrate diversity appeared to decrease in a downstream direction on the larger streams. Mean values for 15 key variables were used to rank stations on the basis of biological conditions.

TABLE OF CONTENTS

ACKNOWLEDGEMENTS	i
DISCLAIMER	i
ABSTRACT	ii
CONTENTS	iv
PREFACE	v
INTRODUCTION	1
RATIONALE, METHODS RESULTS, AND INTERPRETATIONS	
Streamflow	6
Common Ions	10
Algal Nutrients	25
Algal Assay	35
Periphyton Production	39
Periphyton Community Structure	52
Macroinvertebrate Community Structure	64
SUMMARY	75
LITERATURE CITED	78
APPENDIXES	
A. Streams and Stations in the Montana Biological Monitoring Network	81
B.,C. Phosphate Concentrations	84
D.,E. Total Phosphorus Concentrations	86
F.,G. Nitrate Plus Nitrite Concentrations	88
H.,I. Ammonia Concentrations	90
J.,K. Kjeldahl Nitrogen Concentrations	92



PREFACE

The importance of long term monitors is evident when one considers the ecology of our biosphere, because it is being increasingly manipulated and polluted by the civilization of man. This is due to the increased population which results in an increased demand for materials for life and for habitation... (Patrick, 1977)

An interim goal of the 1972 amendments to the Federal Water Pollution Control Act is to have, wherever attainable, fishable and swimmable water by July 1, 1983. The benefits realized by achieving this goal will be substantial, since water quality that permits fishing and swimming is also suitable for most other beneficial uses.

To reach the 1983 goal, the basic biological communities and processes that allow fishing and swimming must be maintained in a healthy balance. For example, algae must not become a nuisance and the small aquatic animals that fish eat must be present in variety and abundance. Until recently, basic biological processes such as photosynthesis and aquatic life forms lower than fish had been given little consideration in water quality management, yet these processes and life forms are basic to the integrity of the entire aquatic ecosystem. Any effects here on the "ground floor" likely will have repercussions on up the food chain.

Chemical and physical properties of water affect living organisms in ways we are just beginning to understand. Aquatic organisms are capable of integrating the many and diverse factors of their environment and of expressing their combined effect in terms of growth, reproductive success, and the resulting community diversity. Aquatic organisms vary in their sensitivity to pollutants, hence some of the more sensitive and tolerant taxa have become useful as water quality indicators. Lower life forms are particularly useful as indicators because almost always they are present in statistically significant numbers.

To maintain water quality for fish and aquatic life is public policy of the State of Montana [Sec. 75-5-101(1), M.C.A. 1979]. Pollution is defined in part as "...contamination, or other alteration of the physical, chemical, or biological properties of any state water..." [Sec. 75-5-103(5), M.C.A. 1979]. To measure our success at protecting aquatic life and controlling pollution we need a good yardstick. What is a better yardstick than the biological organisms and processes themselves? Yet there has been no comprehensive, systematic, and continuing biological monitoring to date in Montana.

The Montana Biological Monitoring Program is designed to help fill this need. The program consists of a network of stations, a battery of variables and a sampling strategy.

The network includes 85 stations on 59 streams statewide, with at least one station in each of the state's major drainage basins. Stations were located mostly on the larger rivers and streams under the assumption that these sites would most accurately reflect water quality conditions basinwide. Stations are grouped geographically into five loops, each with 16 to 20 stations. Thirty-three of the sampling sites are located at or near U.S.G.S. water quality stations and 10 conform to U.S.G.S. NASQAN (National Stream Quality Accounting Network) stations. Streams and stations in the Montana Biological Monitoring Network are listed in Appendix A.

Data are gathered in seven biologically-related areas: streamflow, common constituents (including specific conductance and total alkalinity), algal nutrients (nitrogen and phosphorus), algal growth potential (algal assay), instream periphyton production, periphyton community structure, and macroinvertebrate community structure.

Stations are monitored seasonally during periods of stable flow, once in spring (March-April), once in summer (July-August), and once in fall (September-October). Ice and high flows have proven to be serious impediments to biological sampling. Consequently, sampling in winter and during peak snowmelt will not be pursued, even though these are times of stress for aquatic organisms.

Beginning in 1980, after the seasonal baseline assessment was completed for all 85 stations, the program was streamlined for biennial operation: Stations will be sampled once in summer to permit the evaluation of trends. Only long-term biological monitors--periphyton and macroinvertebrate community structure--will be examined. (These two features are at the heart of the Montana Biological Monitoring Program). An appropriate biological index will be adopted. Certain stations may be dropped and others added. Obviously, the program is not designed for rapid detection of acute problems but rather for evaluation of chronic, long-term trends.

Comments are welcome, especially now when the program is relatively new. All stations, parameters, and procedures are on trial and subject to continuing evaluation. If we have overlooked a stream of particular interest to you, please let us know and give us your reasons why it should be included in the network. We would also like your comments on the overall usefulness of the program to you. It is hoped that these reports will be more than just internal management documents, and that they will aid resource managers, municipalities, industries, and the public in assessing water quality conditions and trends in their areas.

INTRODUCTION

This is the fourth and final report on baseline biological conditions in Montana rivers and streams.

The Eastern Loops (Northeast and Southeast) include waters that traverse largely agricultural lands in Great Plains Montana. Livestock grazing and dryland and irrigated farming are the principal land uses. Oil and natural gas production and, more recently, coal stripmining are the primary extractive industries. The human population is sparse and largely rural, although the area includes Montana's largest city--Billings (pop. ca. 70,000). Major water quality problems in eastern Montana are sediment, salinity, and dewatering (Water Quality Bureau, 1976).

Stream stations covered in this report are listed in Tables 1 and 2, along with legal descriptions and abbreviations used in subsequent tables. All 20 stations in the Northeast loop are within the Missouri River drainage basin. All but two of the 16 stations in the Southeast loop are within the Yellowstone River drainage basin. The stations on Beaver Creek at Wibaux and the Little Missouri River at Capital are geographically south of the Yellowstone River in Montana but included within the drainage area of the Missouri River below the mouth of the Yellowstone.

Variables covered in this report are listed in Table 3. Tests for all variables except certain common constituents and algal growth potential (algal assays) were run seasonally, in March-April 1979 (spring), July 1979 (summer), and October 1979 (fall). Common ions and algal growth potential were determined for samples collected during the summer trip only.

The Eastern loops were run again in the summer of 1980, along with the remaining three loops. When periphyton and macroinvertebrate samples collected on the 1980 visits have been analyzed, evaluation of long-term trends in water quality can begin for all 85 stations statewide.

Table 1. Stream stations covered in this report -- Northeast Loop

Abbreviation	Location	Legal Description
Beaver Creek/Hinsdale	Beaver Creek near Hinsdale at Beaverton	T31N R34E 25BCB
Box Elder Creek	Box Elder Creek near Winnett	T14N R28E 03BAC
Big Muddy Creek	Big Muddy Creek near mouth near Culbertson	T28N R55E 21BDC
Big Spring Creek	Big Spring Creek below Lewistown	T16N R17E 35BDD
Judith River/Utica	Judith River near Utica	T13N R12E 03CAA
Judith River/Danvers	Judith River near Danvers	T18N R16E 32CCD
Judith River/Winifred	Judith River near mouth near Winifred	T23N R16E 03ACD
Milk River/Nashua	Milk River at Nashua near mouth	T27N R41E 01CBC
Missouri River/Winifred	Missouri River below Judith River	T23N R16E 25BAD
Missouri River/Mobridge	Missouri River at Fred Robinson Bridge	T22N R24E 31ABB
Missouri River/ Culbertson	Missouri River at Culbertson	T27N R56E 03BAD
Musselshell River/ Harlowton	Musselshell River at Harlowton	T08N R15E 28AAD
Musselshell River/ Bundy	Musselshell River at Bundy above Roundup	T06N R23E 01ADC
Musselshell River/ Delphia	Musselshell River at Delphia below Roundup	T09N R28E 28CCC
Musselshell River/ Mosby	Musselshell River at Mosby	T14N R30E 11BBB
Poplar River	Poplar River at mouth at Poplar	T27N R50E 12BBC
Redwater River/Circle	Redwater River at Circle	T19N R48E 11CCA
Redwater River/Poplar	Redwater River near mouth near Poplar	T27N R50E 35AAA
Wolf Creek/Stanford	Wolf Creek at Stanford	T16N R12E 07DCC
Wolf Creek/Denton	Wolf Creek at Denton	T18N R14E 14CBB

Table 2. Stream stations covered in this report -- Southeast Loop

Abbreviation	Location	Legal Description
Armell's Creek	East Fork Armells Creek near Colstrip	T03N R41E 28CCD
Beaver Creek/Wibaux	Beaver Creek at Wibaux	T14N R59E 12BDD
Bighorn River	Bighorn River at Bighorn near mouth	T05N R34E 33BBC
Clark's Fork River	Clark's Fork River at Edgar near Laurel	T04S R23E 25BAB
Little Missouri River	Little Missouri River at Capitol	T05S R62E 03BAA
Powder River/Broadus	Powder River at Broadus	T05S R51E 02BCC
Powder River/Locate	Powder River at Locate near Miles City	T08N R51E 23CCD
Rosebud Creek	Rosebud Creek near Colstrip	T02N R43E 29DDA
Shields River	Shields River near mouth near Livingston	T01S R10E 26BBA
Tongue River/Brandenberg	Tongue River at Brandenberg	T01N R44E 14ACC
Tongue River/Miles City	Tongue River at Miles City near mouth	T07N R47E 23DAA
Yellowstone River/ Livingston	Yellowstone River above Livingston	T03S R09E 01CBC
Yellowstone River/ Billings	Yellowstone River at East Bridge in Billings	T01N R26E 34AAB
Yellowstone River/ Huntley	Yellowstone River near Huntley	T02N R27E 25CDB
Yellowstone River/ Forsyth	Yellowstone River at Forsyth	T06N R40E 23BBC
Yellowstone River/ Sidney	Yellowstone River at Sidney	T22N R59E 09CCD

Table 3. Variables covered in this report

Instantaneous Streamflow (m^3/sec)

Common Constituents

- Cation Ratio: Ca:Mg:Na (as meq/l)
- Anion Ratio: $\text{HCO}_3:\text{SO}_4:\text{Cl}$ (as meq/l)
- Specific Conductance (micromhos @ 25 C)
- Sodium Adsorption Ratio (SAR)
- Total Alkalinity (mg/l CaCO_3)
- Total Hardness (mg/l CaCO_3)
- Field Water Temperature ($^{\circ}\text{C}$)
- Field pH (pH units)
- Total Suspended Sediment (mg/l)
- Laboratory Turbidity (NTU)

Algal Nutrients

- $\text{NO}_2+\text{NO}_3\text{-N}$; $\text{NH}_3+\text{NH}_4\text{-N}$; $\text{NH}_3\text{-N}$;
Kjeldahl-N; $\text{PO}_4\text{-P}$; Total P (all in mg/l)
- Total Soluble Inorganic Nitrogen ($\text{NO}_2+\text{NO}_3\text{-N}$
plus $\text{NH}_3+\text{NH}_4\text{-N}$: Phosphate Phosphorus ($\text{PO}_4\text{-P}$) Ratio
- TSIN and Total P as % of recommended maximum instream
levels (0.35 mg/l TSIN and 0.05 mg/l Total P)

Algal Assay

- Control Standing Crop (mg/l)
- Nutrient Spike Standing Crop (mg/l)

Periphyton Production

- Chlorophyll a Accrual ($\text{mg}/\text{m}^2/\text{day}$)
- Biomass Accrual ($\text{mg}/\text{m}^2/\text{day}$)
- Autotrophic Index
- Chlorophyll a/Pheophytin a Ratio ($\text{OD}663_{\text{p}}/\text{OD}663_{\text{a}}$)
- Carotene/Chlorophyll Ratio ($\text{OD}430/\text{OD}663$)

Periphyton Community Structure

- Rank of diatoms relative to other algae
- Number of Diatom Species
- Diatom Species Diversity (d)

Macroinvertebrate Community Structure

- Mean PRA Major Macroinvertebrate Orders
- Number of Macroinvertebrate Taxa
- Macroinvertebrate Genus Diversity (d)
- Number of Organisms Collected



RATIONALE, METHODS, RESULTS, AND INTERPRETATIONS

STREAMFLOW

Rationale

Accurate measurements of streamflow are essential for calculating loads of dissolved constituents, particularly nutrients. Many aquatic organisms have specific instream flow requirements for various activities. Exceptionally high and low flows--overbank flooding and complete dewatering in the extremes--are rather traumatic events for a river and its aquatic life. Periodic streamflow measurements also circumscribe a stream's size, which in turn dictates the nature of the aquatic community it can support.

Methods

Flow rates at the following stations were measured with a Marsh-McBirney electronic current meter: Beaver Creek/Hinsdale, Box Elder Creek, Big Spring Creek, the three Judith River stations, Missouri River/Winifred, Redwater River/Poplar, and the two Wolf Creek stations (Northeast Loop); Armell's Creek, Little Missouri River, and the Shield's River (Southeast Loop). A straight section of stream with a uniform cross-section and a smooth bottom was chosen whenever available. A measuring tape was stretched across the channel and depths and velocities were recorded at selected points such that no more than 10 percent of the total discharge fell between two consecutive points. Total instantaneous discharge was then estimated by summing flows for each of the measured subsections.

Where biological monitoring and U.S.G.S. gaging stations coincide, streamflow measurements were obtained from the Helena, Billings and Fort Peck offices of the U.S. Geological Survey, Water Resources Division. Streamflows for the Musselshell River at Bundy and the Yellowstone River at Huntley were estimated from flows measured at U.S.G.S. stations at Roundup and Billings, respectively. The National Weather Service, Billings and Great Falls, provided flow data for the Clarks Fork River. Flows in the Missouri River near Winifred could not be estimated accurately because of the size of the stream and the considerable distance to the nearest U.S.G.S. gaging station.

Results

Instantaneous streamflows are presented in Tables 4 and 5.

Interpretation

In the Northeast Loop, mean instantaneous streamflow ranged from 0.3 m³/sec in Wolf Creek at Stanford to 308.26 m³/sec in the Missouri River at Culbertson. Missouri River/Winifred flows probably were of the same order of magnitude as Missouri River/Mobridge flows. Seasonal flows for most streams

declined appreciably from spring to summer and again from summer to fall, reflecting the early snowmelt/runoff cycle in northeastern Montana and subsequent irrigation usage and natural depletions.

In the Southeast Loop, mean instantaneous streamflow ranged from practically nil in Armell's Creek to 372.03 m³/sec in the Yellowstone River at Forsyth. Large rivers originating in the mountains (Bighorn, Clark's Fork and Yellowstone) peaked later than the smaller prairie streams, resulting in a mean summer flow that was significantly larger than the mean spring flow for the Southeast Loop as a whole. Mean fall streamflow was only a quarter of mean summer flow, reflecting both natural and agricultural depletions.

Three streams exhibited no surface flows on one or more visits during the course of this study. These streams were Armell's Creek, Box Elder Creek, and the Little Missouri River.

Table 4. Instantaneous Streamflow (m³/sec) -- Northeast Loop

Station	Spring	Summer	Fall	Mean
Beaver Creek/Hinsdale	FNM	.17	.12	.14
Box Elder Creek	6.82	0.00	0.00	3.41
Big Muddy Creek	25.49	.17	.01	8.56
Big Spring Creek	FNM	4.84	5.22	5.03
Judith River/Utica	.19	2.25	.62	1.02
Judith River/Danvers	FNM	16.99(E)	12.04(E)	14.52(E)
Judith River/Winifred	FNM	15.76	12.41	14.08
Milk River/Nashua	212.40	26.03	3.68	80.70
Missouri River/ Winifred	FNM	FNM	FNM	FNM
Missouri River/ Moberg	410.64	297.36	166.80	291.6
Missouri River/ Culbertson	FNM	396.48	220.05	308.26
Musselshell River/ Harlowton	7.10	.96	.84	2.97
Musselshell River/ Bundy	32.00(E)	13.51(E)	2.02(E)	15.84(E)
Musselshell River/ Delphia	35.40	12.40	2.09	16.63
Musselshell River/ Mosby	56.64	4.19	2.54	21.12
Poplar River	56.64	1.70	.45	19.60
Redwater River/Circle	7.08	.08	.01	2.39
Redwater River/Poplar	FNM	.73	.35	.54
Wolf Creek/Stanford	.15	.14	.09	.13
Wolf Creek/Denton	.66	.14	.32	.37
Mean	65.48	44.10	22.61	41.50

FNM: Flow not measured

(E): Estimate

Table 5. Instantaneous Streamflow (m³/sec) - Southeast Loop

Station	Spring	Summer	Fall	Mean
Armell's Creek	.06(E)	< .01	0.00	.02
Beaver Creek/Wibaux	.42	.06	.03	.17
Bighorn River	157.74	175.50	90.68	141.31
Clark's Fork River	12.74	69.38	10.76	30.96
Little Missouri River	FNM	.66	0.00	.33
Powder River/Broadus	23.16	8.10	5.61	12.29
Powder River/Locate	75.33	8.66	1.32	28.44
Rosebud Creek	6.71	1.10	.85	2.89
Shields River	9.57	FNM	3.71	6.64
Tongue River/ Brandenberg	17.67	14.73	6.81	13.07
Tongue River/ Miles City	33.98	7.22	2.94	14.71
Yellowstone River/ Livingston	30.58	252.05	48.17	110.27
Yellowstone River/ Billings	142.45	495.6	71.65	236.57
Yellowstone River/ Huntley	151.51(E)	495.6(E)	71.65(E)	239.59(E)
Yellowstone River/ Forsyth	387.98	574.90	153.21	372.03
Yellowstone River/ Sidney	487.10	438.96	162.56	362.87
Mean	102.47	169.50	39.37	102.38

FNM: Flow not measured

(E): Estimate

COMMON CONSTITUENTS

Rationale

Common ions are the basic ingredients of the chemical "soup" in which aquatic organisms live. Their relative proportions often dictate the nature of plant and animal communities inhabiting surface waters.

Specific conductance is a measure of osmotic stress on organisms--both aquatic and terrestrial--that live in, drink of or are irrigated by the water in question. Too much sodium in relation to other cations (measured by the sodium adsorption ratio or SAR) may destroy soil structure and inhibit the growth of irrigated crops.

Alkalinity is a measure of the acid-neutralizing capacity of water and thereby an indicator of a water's resiliency to acid rainfall or mine drainage. It is generally proportional to a water's basic fertility or productivity. Alkalinity and pH are closely interrelated.

Hardness is a measure of a water's capacity for precipitating soap. Soap is precipitated chiefly by the calcium and magnesium ions commonly present in water. Hardness was calculated from the concentrations of these two cations and expressed as calcium carbonate. The susceptibility of a water's biological community to toxicity by heavy metals is inversely proportional to the water's hardness; the more calcium and magnesium dissolved in a water, the less toxic will be a given concentration of heavy metals.

The metabolic rate of aquatic organisms roughly doubles with every 10° C increase in temperature. Aquatic organisms often are very sensitive to temperature extremes, particularly in the high range.

Suspended sediment in excess will interfere with certain aquatic biological processes and activities, for example breathing and spawning. It will also cause scouring and prevent secure attachment by sessile benthic organisms. Waters normally containing 80 to 400 mg/l suspended solids are unlikely to support good freshwater fisheries (F.W.P.C.A., 1968). Excessive turbidity will limit light penetration to bottom-living plants.

Methods

Unpreserved and unfiltered grab samples were collected in one liter plastic bottles and transported under ice back to the laboratory. Analytical procedures followed those of the American Public Health Association (1971; 1975) or the U.S. Environmental Protection Agency (1974). Specific conductance was measured with a Wheatstone bridge. Calcium, magnesium and sodium were measured by atomic absorption. Bicarbonate and total alkalinity were measured by the automated methyl orange method or by titration with 0.02 N H₂SO₄ to a pH 4.5 endpoint. Sulfate was determined by the automated methyl thymol blue method. Chloride was measured by the automated mercuric

thiocyanate method. Total hardness was calculated from calcium and magnesium analyses and the sodium adsorption ratio determined from sodium, calcium and magnesium results. pH measurements were made on site with a mini-field pH meter with a combination gel-filled electrode.

Samples to be analyzed for turbidity and total suspended solids were collected unpreserved in one pint bottles with a depth-integrating type DH-48 suspended sediment sampler with a 1/4 inch orifice. A measuring tape was stretched across the channel where depths were not prohibitive. The sampler was then lowered from the water surface to the streambed and back at the same rate at 10 to 20 equally spaced verticals in the stream cross section, depending on stream width. This method resulted in a water-sediment sample that was weighted according to velocity at each increment of depth and at each of the verticals. Samples were then transported to the laboratory and analyzed following approved methods (A.P.H.A., 1971, 1975; EPA, 1974). Total suspended solids were measured by the filtration, evaporation at 105°C, gravimetric method. Turbidity was determined nephelometrically. Water temperatures were measured on site at the time of sample collection with a pocket field thermometer accurate to plus or minus 1.0°C.

Results

Values for the common constituents in eastern Montana waters are presented in Tables 6 through 17.

Interpretation

Stream stations in eastern Montana have a varied ionic makeup, averaging a bit more sodium than calcium or magnesium and about twice as much sulfate as bicarbonate. Chloride is not a significant anion in streams of the eastern loops relative to bicarbonate and sulfate. The larger and longer streams in eastern Montana typically begin in upland regions as calcium-bicarbonate waters and pick up more sodium and sulfate as they descend into the prairie.

Using summer conductivity data, Armell's Creek and both Redwater River stations are classified as very high salinity waters, meaning they are not suitable for irrigation under ordinary conditions. Beaver Creek at Wibaux, Big Muddy Creek, Wolf Creek at Denton, the Little Missouri and Powder rivers, and the Musselshell River at Mosby all have borderline salinity conditions. In addition to their very high salinity, both Redwater River stations have a preponderance of the sodium ion and would pose a high sodium hazard based on their SAR values. Armell's Creek, Big Muddy Creek and Beaver Creek at Wibaux, the Little Missouri River, and Powder River at Locate all have moderate sodium levels while the remaining streams sampled in eastern Montana would pose a low sodium hazard (Richards, 1969).

All waters measured in eastern Montana are classed as "moderately hard" to "very hard" and would be relatively insensitive to heavy metals contamination (Todd, 1969). Furthermore, these waters all give a neutral to alkaline reaction and are well buffered, indicating they would be resistant to acid rainfall and acid-mine drainage.

Eastern Montana streams exhibit the greatest range in temperature of any waters in the state, from 0°C in winter upwards toward 30°C in summer.

Suspended sediment and turbidity measurements at both Powder River stations averaged one, two and in some cases three orders of magnitude higher than mean values for these parameters at other stations in eastern Montana. Four additional stream stations with notably poor water clarity and high sediment values were the Clark's Fork of the Yellowstone, Milk River at Nashua, Tongue River at Miles City and the Redwater River near Poplar. Suspended sediment and turbidity values were generally highest in spring and lowest in fall, being closely and directly related to stream discharge.

Table 6. Total Alkalinity (mg/l CaCO_3), Total Hardness (mg/l CaCO_3), Sodium Adsorption Ratio (SAR), and common ion ratios (as meq/l) -- Northeast Loop

Station	Total Alkalinity	Total Hardness	Sodium Adsorption Ratio	Ca:Mg:Na	HCO_3 : SO_4 :Cl
Beaver Creek/Hinsdale	226	354	4.1	1:1:3	4:9:1
Box Elder Creek	DRY	DRY	DRY	DRY	DRY
Big Muddy Creek	468	492	6.9	1:3:6	23:44:1
Big Spring Creek	184	316	0.3	9:5:1	58:51:1
Judith River/Utica	165	193	1.7	2:1:2	112:25:1
Judith River/Danvers	196	320	0.5	4:3:1	36:31:1
Judith River/Winifred	165	402	0.9	2:2:1	23:42:1
Milk River/Nashua	220	300	3.1	1:1:2	11:16:1
Missouri River/ Winifred	148	203	0.9	2:1:1	13:9:1
Missouri River/ Moberge	146	237	0.9	2:1:1	12:11:1
Missouri River/ Culbertson	148	254	2.3	1:1:2	12:22:1
Musselshell River/ Harlowton	226	359	1.4	2:1:1	22:27:1
Musselshell River/ Bundy	232	408	2.0	1:1:1	15:24:1
Musselshell River/ Delphia	245	457	2.2	1:1:1	13:22:1
Musselshell River/ Mosby	238	573	3.8	1:1:2	9:29:1
Poplar River	352	177	5.7	1:1:5	4:2:1
Redwater River/ Circle	477	1216	9.6	1:2:5	19:99:1
Redwater River/ Poplar	241	529	10.3	1:3:9	9:63:1
Wolf Creek/Stanford	199	246	0.1	13:8:1	64:18:1
Wolf Creek/Denton	259	798	3.5	1:2:2	6:20:1
Mean	239	412	3.2	1:1:2	11:24:1

Table 7. Total Alkalinity (mg/l CaCO₃), Total Hardness (mg/l CaCO₃), Sodium Adsorption Ratio (SAR), and common ion ratios (as meq/l) -- Southeast Loop

Station	Total Alkalinity	Total Hardness	Sodium Adsorption Ratio	Ca:Mg:Na	HCO ₃ :SO ₄ :Cl
Armell's Creek	213	2390	4.8	1:4:2	3:51:1
Beaver Creek/Wibaux	365	633	6.0	1:1:3	28:75:1
Bighorn River	169	310	2.2	2:1:2	10:18:1
Clark's Fork River	80	111	0.5	3:1:1	24:15:1
Little Missouri River	228	641	4.4	1:1:2	8:31:1
Powder River/ Broadus	162	555	3.1	3:1:3	1:5:1
Powder River/Locate	200	595	5.3	2:1:3	1:5:1
Rosebud Creek	359	589	1.4	1:3:1	38:40:1
Shields River	188	189	0.7	3:1:1	19:3:1
Tongue River/ Brandenberg	146	222	0.9	2:2:1	37:38:1
Tongue River/ Miles City	177	241	1.4	1:1:1	39:40:1
Yellowstone River/ Livingston	54	47	0.5	2:1:1	9:2:1
Yellowstone River/ Billings	79	91	0.6	2:1:1	11:4:1
Yellowstone River/ Huntley	68	79	0.5	2:1:1	15:6:1
Yellowstone River/ Forsyth	94	126	1.0	2:1:1	13:12:1
Yellowstone River/ Sidney	120	159	1.4	2:1:1	11:11:1
Mean	169	436	2.0	1:1:1	5:16:1

Table 8. Specific Conductance (umhos @ 25C) -- Northeast Loop

Station	Spring	Summer	Fall	Mean
Beaver Creek/Hinsdale	501	1429	1837	1256
Box Elder Creek	1725	DRY	7420	4572
Big Muddy Creek	945	2226	2675	1949
Big Spring Creek	777	604	592	658
Judith River/Utica	955	380	645	660
Judith River/Danvers	1025	660	655	780
Judith River/Winifred	1643	866	954	1154
Milk River/Nashua	473	1094	1457	1008
Missouri River/ Winifred	1452	503	643	866
Missouri River/ Mabridge	835	547	540	641
Missouri River/ Culbertson	ICE	806	816	811
Musselshell River/ Harlowton	902	883	970	918
Musselshell River/ Bundy	1621	1087	1781	1496
Musselshell River/ Delphia	1735	1254	1687	1559
Musselshell River/ Mosby	2038	1784	2292	2038
Poplar River	311	1039	2019	1123
Redwater River/ Circle	977	4652	4107	3245
Redwater River/ Poplar	1047	3294	3084	2475
Wolf Creek/Stanford	521	460	534	505
Wolf Creek/Denton	1941	2136	1662	1913
Mean	1128	1353	1818	1440

Table 9. Specific Conductance (umhos @ 25C) -- Southeast Loop

Station	Spring	Summer	Fall	Mean
Armell's Creek	3916	5076	DRY	4496
Beaver Creek/Wibaux	1548	2444	2440	2144
Bighorn River	1400	900	889	1063
Clark's Fork River	1148	260	909	2317
Little Missouri River	529	2142	2367	1679
Powder River/Broadus	2646	1693	2474	2271
Powder River/Locate	1649	2262	2622	2178
Rosebud Creek	1395	1261	1495	1384
Shields River	561	429	496	495
Tongue River/ Brandenberg	1148	542	938	876
Tongue River/ Miles City	713	677	1002	797
Yellowstone River/ Livingston	338	127	275	247
Yellowstone River/ Billings	793	221	565	526
Yellowstone River/ Huntley	796	197	600	531
Yellowstone River/ Forsyth	1130	366	754	750
Yellowstone River/ Sidney	1183	509	851	848
Mean	1306	1194	1245	1248

Table 10. Field Water Temperature ($^{\circ}\text{C}$) -- Northeast Loop

Station	Spring	Summer	Fall	Mean
Beaver Creek/Hinsdale	0.0	23.0	11.0	11.3
Box Elder Creek	3.0	DRY	12.5	7.8
Big Muddy Creek	0.0	22.0	11.5	11.2
Big Spring Creek	7.5	19.0	9.5	12.0
Judith River/Utica	4.0	17.0	12.0	11.0
Judith River/Danvers	4.5	18.0	11.0	11.2
Judith River/Winifred	6.5	25.0	10.0	13.8
Milk River/Nashua	4.0	22.0	11.0	12.3
Missouri River/ Winifred	4.5	22.0	10.5	12.3
Missouri River/ Moberg	3.0	20.0	11.5	11.5
Missouri River/ Culbertson	ICE	17.0	9.5	13.2
Musselshell River/ Harlowton	10.5	24.0	9.0	14.5
Musselshell River/ Bundy	5.0	19.0	11.0	11.7
Musselshell River/ Delphia	5.5	21.0	12.0	12.8
Musselshell River/ Mosby	3.0	25.0	13.0	13.7
Poplar River	0.0	19.5	11.0	10.2
Redwater River/Circle	0.0	22.5	12.0	11.5
Redwater River/Poplar	0.0	23.0	9.0	10.7
Wolf Creek/Stanford	6.5	18.0	12.0	12.2
Wolf Creek/Denton	11.5	19.5	11.5	14.2
Mean	4.2	20.9	11.0	12.0

Table 11. Field Water Temperature (°C) -- Southeast Loop

Station	Spring	Summer	Fall	Mean
Armell's Creek	2.5	23.5	DRY	13.0
Beaver Creek/Wibaux	1.0	24.5	12.0	12.5
Bighorn River	4.0	18.0	15.0	12.3
Clark's Fork River	2.5	17.5	15.0	11.7
Little Missouri River	0.0	27.0	9.5	12.2
Powder River/Broadus	5.0	24.0	10.5	39.5
Powder River/Locate	3.0	24.0	10.5	37.5
Rosebud Creek	1.0	23.5	10.5	11.2
Shields River	2.5	14.0	13.0	9.8
Tongue River/ Brandenberg	2.0	26.0	12.0	13.3
Tongue River/ Miles City	2.0	23.0	10.0	11.7
Yellowstone River/ Livingston	2.0	17.0	12.0	10.3
Yellowstone River/ Billings	5.5	19.0	17.5	14.0
Yellowstone River/ Huntley	5.0	19.0	14.5	12.8
Yellowstone River/ Forsyth	3.5	19.0	14.5	12.3
Yellowstone River/ Sidney	2.0	21.0	11.5	11.5
Mean	2.7	21.2	12.5	12.2

Table 12. Field pH -- Northeast Loop

Station	Spring	Summer	Fall	Mean
Beaver Creek/Hinsdale	7.00	8.05	8.20	7.75
Box Elder Creek	8.10*	DRY	8.43	8.26
Big Muddy Creek	7.68*	8.75	8.87	8.43
Big Spring Creek	8.31*	8.50	8.55	8.45
Judith River/Utica	8.23*	8.49	8.23	8.32
Judith River/Danvers	8.31*	8.40	8.68	8.46
Judith River/Winifred	8.38*	8.28	8.52	8.39
Milk River/Nashua	7.37*	8.30	8.44	8.04
Missouri River/ Winifred	8.37*	8.67	8.37	8.47
Missouri River/ Mobridge	8.10	8.57	8.75	8.47
Missouri River/ Culbertson	ICE	8.32	8.49	8.40
Musselshell River/ Harlowton	8.43*	8.50	8.49	8.47
Musselshell River/ Bundy	8.10	8.30	8.36	8.25
Musselshell River/ Delphia	8.20	8.35	8.42	8.32
Musselshell River/ Mosby	8.00	8.37	8.02	8.13
Poplar River	7.54*	8.55	8.78	8.29
Redwater River/Circle	7.80	8.29	8.65	8.25
Redwater River/Poplar	7.00	8.60	8.54	8.05
Wolf Creek/Stanford	8.08*	8.32	8.39	8.26
Wolf Creek/Denton	8.47	8.35	8.44	8.42
Mean	7.97	8.42	8.48	8.29

* - Lab determination. Field measurement not made.

Table 13. Field pH -- Southeast Loop

Station	Spring	Summer	Fall	Mean
Armell's Creek	7.70	8.37	DRY	8.04
Beaver Creek/Wibaux	7.90	8.05	8.23	8.06
Bighorn River	8.20	8.35	8.56	8.37
Clark's Fork River	7.51	7.90	8.39	7.93
Little Missouri River	7.20	8.15	7.97	7.77
Powder River/Broadus	7.80	8.38	8.08	8.09
Powder River/Locate	8.10	8.39	8.38	8.29
Rosebud Creek	8.40	8.30	8.17	8.29
Shields River	7.00	8.35	8.27	7.87
Tongue River/ Brandenberg	8.10	8.50	8.03	8.21
Tongue River/ Miles City	8.20	8.40	8.70	8.43
Yellowstone River/ Livingston	7.92	8.25	8.70	8.29
Yellowstone River/ Billings	8.20	8.20	8.45	8.28
Yellowstone River/ Huntley	7.80	8.10	8.62	8.17
Yellowstone River/ Forsyth	7.90	8.20	8.68	8.26
Yellowstone River/ Sidney	8.33*	8.42	8.55	8.43
Mean	7.89	8.27	8.38	8.18

* - Lab determination. Field measurement not made.

Table 14. Total Suspended Sediment (mg/l) -- Northeast Loop

Station	Spring	Summer	Fall	Mean*
Beaver Creek/Hinsdale	578	44.5	14.1	212
Box Elder Creek	228	DRY	8.6	118
Big Muddy Creek	42.2	93.8	48.3	61.4
Big Spring Creek	44.5	18.1	20.0	27.5
Judith River/Utica	< 5.1	< 5.5	< 5.3	< 5.3
Judith River/Danvers	237	60.4	49.5	116
Judith River/Winifred	433	86.1	52.2	190
Milk River/Nashua	946	167	24.6	379
Missouri River/ Winifred	390	52.3	38.2	160
Missouri River/ Moberge	355	62.7	15.8	144
Missouri River/ Culbertson	ICE	259	32.3	146
Musselshell River/ Harlowton	31.6	8.0	41.5	27.0
Musselshell River/Bundy	407	179	12.2	199
Musselshell River/ Delphia	515	166	14.5	232
Musselshell River/ Mosby	684	115	7.9	269
Poplar River	196	99.3	105	133
Redwater River/Circle	51.2	37.6	25.2	38.0
Redwater River/Poplar	762	28.4	16.2	269
Wolf Creek/Stanford	29.1	9.5	20.2	19.6
Wolf Creek/Denton	39.2	6.3	15.4	20.3
Mean *	314	78.9	28.4	139

* Values reported as less than "x" mg/l used as actual values in determination of means.

Table 15. Total Suspended Sediment (mg/l) -- Southeast Loop

Station	Spring	Summer	Fall	Mean*
Armell's Creek	7.8	< 5.8	DRY	< 6.8
Beaver Creek/Wibaux	54.5	27.7	3.3	28.5
Bighorn River	255	94.7	10.3	120
Clark's Fork River	630	958	30.2	539
Little Missouri River	376	42.9	17.5	145
Powder River/Broadus	8260	893	68.6	3074
Powder River/Locate	3220	741	45.6	1335
Rosebud Creek	305	255	18.8	193
Shields River	57.4	48.4	7.7	37.8
Tongue River/ Brandenberg	310	64.7	5.4	127
Tongue River/ Miles City	1000	50.1	< 5.7	< 352
Yellowstone River/ Livingston	6.3	21.4	7.0	11.6
Yellowstone River/ Billings	148	68.9	12.3	76.4
Yellowstone River/ Huntley	151	44.8	11.4	69.1
Yellowstone River/ Forsyth	493	73.8	13.4	193
Yellowstone River/ Sidney	494	78.3	18.8	197
Mean *	986	217	18.4	415

* Values reported as less than "x" mg/l used as actual values in determination of means.

Table 16. Laboratory Turbidity (NTU) -- Northeast Loop

Station	Spring	Summer	Fall	Mean
Beaver Creek/Hinsdale	355	24.0	8.2	129
Box Elder Creek	79.0	DRY	2.5	40.8
Big Muddy Creek	63.0	37.2	23.0	41.1
Big Spring Creek	18.5	3.3	4.4	8.7
Judith River/Utica	0.7	0.7	0.3	0.6
Judith River/Danvers	79.0	11.5	11.0	33.8
Judith River/Winifred	105	24.0	13.5	47.5
Milk River/Nashua	510	62.	7.6	193
Missouri River/Winifred	140	16.0	11.5	55.8
Missouri River/Mobridge	90.0	21.0	3.7	38.2
Missouri River/ Culbertson	ICE	98.	13.5	55.8
Musselshell River/ Harlowton	2.7	2.4	5.1	3.4
Musselshell River/ Bundy	150	62.0	5.0	72.3
Musselshell River/ Delphia	215	59.0	5.9	93.3
Musselshell River/ Mosby	260	54.0	3.4	106
Poplar River	160	58.0	28.0	82.0
Redwater River/Circle	57.0	16.0	9.6	27.5
Redwater River/Poplar	400	8.0	5.2	138
Wolf Creek/Stanford	15.2	5.3	7.8	9.4
Wolf Creek/Denton	13.0	1.5	6.5	7.0
Mean	143	29.7	8.8	59.5

Table 17. Laboratory Turbidity (NTU) -- Southeast Loop

Station	Spring	Summer	Fall	Mean
Armell's Creek	6.5	0.9	DRY	3.7
Beaver Creek/Wibaux	30.0	4.4	2.6	12.3
Bighorn River	105	14.5	3.7	41.1
Clark's Fork River	335	390	9.4	245
Little Missouri River	340	14.0	10.2	121.4
Powder River/Broadus	3250	435	35.0	1240
Powder River/Locate	4200	376	23.0	1533
Rosebud Creek	145	132	9.8	95.6
Shields River	23.0	11.5	2.4	12.3
Tongue River/ Brandenberg	94.0	24.0	3.6	40.5
Tongue River/ Miles City	500	24.0	1.7	175
Yellowstone River/ Livingston	3.0	2.7	1.8	2.5
Yellowstone River/ Billings	62.0	16.5	4.6	27.7
Yellowstone River/ Huntley	58.0	8.4	4.2	23.5
Yellowstone River/ Forsyth	190	18.0	3.4	70.5
Yellowstone River/ Sidney	240	33.0	6.5	93.2
Mean	599	94.0	8.2	238



ALGAL NUTRIENTS

Rationale

Nitrogen and phosphorus are the two elements most commonly limiting algal growth in lakes and streams. Phosphorus is usually limiting in lakes because many common lake algae can use atmospheric nitrogen. These nitrogen-fixing algae are not common in streams, therefore nitrogen is more often a limiting nutrient in flowing water. Only the soluble inorganic forms of these two nutrients -- nitrate, nitrite and ammonia nitrogen and orthophosphate -- are readily available for plant uptake. The sum of the soluble inorganic nitrogen fractions is called total soluble inorganic nitrogen or TSIN.

Some indication of whether nitrogen or phosphorus is growth limiting may be obtained by determining the weight ratio of the appropriate forms of nitrogen and phosphorus found in a river, and comparing that with the stoichiometric ratio required for growth (Zison et al., 1977). Specifically, let

$$R = \frac{[\text{TSIN}]}{[\text{PO}_4 - \text{P}]}$$

where [TSIN] equals the concentration of total soluble inorganic nitrogen as N in mg/l and $[\text{PO}_4 - \text{P}]$ equals the concentration of phosphate as P in mg/l. If R is greater than 10, phosphorus is more likely limiting than nitrogen. If R is less than 5, nitrogen is more likely limiting than phosphorus. If R is less than 10 but greater than 5, it's a tossup as to which one is limiting.

Nuisance growths of aquatic plants in streams usually can be avoided if total phosphorus is kept below 0.05 mg/l (Mackenthun, 1969) and if TSIN remains less than 0.35 mg/l (Muller, 1953). The total phosphorus criterion is particularly applicable if the stream enters a standing body of water, which is eventually true of many streams in eastern Montana. When instream total phosphorus and TSIN values are computed as percentages of these critical levels, nuisance growths can be expected where both total phosphorus and TSIN are significantly greater than 100 percent, other factors being amenable to algae growth.

Ammonia is composed of two fractions, ionized (NH_4^+) and un-ionized (NH_3). In addition to being an algal nutrient, the un-ionized fraction is acutely toxic to certain aquatic organisms at relatively low concentrations. One criterion for protection of freshwater aquatic life is 0.016 mg/l NH_3 as N (Thurston et al., 1979). The fraction of un-ionized ammonia in the total ammonia complement increases with temperature and pH.

Municipal, industrial and agricultural wastes are the principal sources of excess ammonia and other algal nutrients in surface waters.

Methods

Unfiltered grab samples were collected in one-liter plastic bottles, each preserved with 4 ml of 1+1 H_2SO_4 and transported under ice back to the laboratory. Analytical procedures followed the American Public Health Association (1971; 1975) or the U.S. Environmental Protection Agency (1974).

Phosphate phosphorus was measured by the automated ascorbic acid method. Total phosphorus also was determined by the automated ascorbic acid method following persulfate digestion. Nitrate plus nitrite nitrogen was measured by the automated cadmium reduction method. Total Kjeldahl nitrogen was determined by the automated phenolate procedure following manual digestion. Total ammonia was measured by the automated phenolate method. Un-ionized ammonia was calculated on the basis of stream temperature, pH, and total ammonia results.

Results

Measured algal nutrient levels for the 1979 sampling season are listed in Appendixes B through K. TSIN:PO₄-P ratios are presented in Tables 18 and 19. Tables 20 through 23 give instream TSIN and total phosphorus values as percentages of maximum recommended instream concentrations. Un-ionized ammonia-nitrogen concentrations are presented in Tables 24 and 25.

Interpretations

As with streams in western Montana (Bahls et al., 1979), nutrient ratios were variable from season to season. Although generally both nitrogen and phosphorus concentrations decreased over the summer months, the drop in nitrogen was less than the drop in phosphorus relative to their initial spring values. Consequently, most waters tended to become more phosphorus limited, i.e., have higher N:P ratios, toward autumn.

Based on nutrient ratios calculated from data averaged over all three seasons, just four streams--the Judith River, Armell's, Big Spring and Wolf Creeks--were clearly phosphorus limited. Moreover, these were the only four streams that were phosphorus limited during the critical summer algae growing season. (Several additional streams were phosphorus limited in the fall only.) The remaining streams all tended to be nitrogen limited on the average.

Several stations had mean values for both nitrogen and phosphorus in excess of recommended instream concentrations. These were Big Spring Creek, Judith River at Danvers and Winifred, Missouri River at Winifred, Armell's Creek, Clark's Fork River, and the Yellowstone River at Billings. Many other stations had excess levels of both nutrients at certain times of the year, particularly in spring. Even though nutrient criteria are commonly exceeded in eastern Montana's prairie streams, nuisance algae growths are uncommon because of the typically turbid waters and unstable bottoms. However, algae blooms can be expected where these waters are impounded and their light-blocking sediments are permitted to settle.

Only the Yellowstone River at Billings recorded an un-ionized ammonia level in excess of the criterion to protect freshwater aquatic life. Since this station is above the outfall from the Billings wastewater treatment plant, the most probable source of elevated ammonia in the river at this point is the Yegen Drain, which enters only a short distance upstream. According to data in the files of the Water Quality Bureau, the Yegen Drain typically discharges from 20 to 30 cubic feet per second of water containing up to 6.7 mg/l of total ammonia as N.

Table 18. Ratio of total soluble inorganic nitrogen ($\text{NO}_2 + \text{NO}_3\text{-N}$ plus $\text{NH}_4 + \text{NH}_3\text{-N}$) to phosphate phosphorus (PO_4 as mg/l P) -- Northeast Loop

Station	Spring	Summer	Fall	Mean*
Beaver Creek/Hinsdale	1:2	< 1:3	2:1	1:2
Box Elder Creek	1:1	DRY	8:1	1:1
Big Muddy Creek	2:1	1:2	1:1	2:1
Big Spring Creek	16:1	10:1	243:1	19:1
Judith River/Utica	> 50:1	20:1	> 80:1	150:1
Judith River/Danvers	8:1	31:1	90:1	18:1
Judith River/Winifred	5:1	12:1	190:1	9:1
Milk River/Nashua	1:1	< 1:4	< 1:1	1:2
Missouri River/ Winifred	6:1	< 1:2	12:1	6:1
Missouri River/ Mobridge	2:1	< 1:2	< 3:1	1:1
Missouri River/ Culbertson	ICE	1:1	6:1	2:1
Musselshell River/ Harlowton	< 1:1	< 3:1	> 20:1	1:1
Musselshell River/ Bundy	1:1	< 1:1	10:1	1:1
Musselshell River/ Delphia	1:1	< 1:2	> 10:1	1:1
Musselshell River/ Mosby	1:2	< 1:2	3:1	1:2
Poplar River	2:1	1:3	< 4:1	1:1
Redwater River/Circle	6:1	1:1	< 4:1	5:1
Redwater River/Poplar	2:1	< 2:1	**	1:1
Wolf Creek/Stanford	27:1	22:1	78:1	40:1
Wolf Creek/Denton	105:1	4930:1	150:1	299:1
Mean *	3:1	11:1	31:1	5:1

*Assumes concentrations less than 0.01 mg/l TSIN and 0.001 mg/l phosphate phosphorus equal zero.

**Not determinable due to non-detectable TSIN and phosphate phosphorus

Table 19. Ratio of total soluble inorganic nitrogen ($\text{NO}_2 + \text{NO}_3\text{-N}$ plus $\text{NH}_4 + \text{NH}_3\text{-N}$) to phosphate phosphorus (PO_4 as mg/l P) -- Southeast Loop

Station	Spring	Summer	Fall	Mean*
Armell's Creek	20:1	6:1	DRY	18:1
Beaver Creek/Wibaux	6:1	<3:1	**	6:1
Bighorn River	2:1	5:1	80:1	4:1
Clark's Fork River	2:1	1:2	166:1	2:1
Little Missouri River	1:1	< 1:1	2:1	1:1
Powder River/Broadus	1:4	1:1	< 1:1	1:3
Powder River/Locate	1:4	1:3	2:1	1:4
Rosebud Creek	3:1	1:1	2:1	2:1
Shields River	5:1	6:1	> 270:1	6:1
Tongue River/ Brandenberg	2:1	< 1:1	< 4:1	2:1
Tongue River/ Miles City	1:2	1:1	> 80:1	1:1
Yellowstone River/ Livingston	9:1	1:1	25:1	5:1
Yellowstone River/ Billings	7:1	1:1	43:1	6:1
Yellowstone River/ Huntley	5:1	1:1	11:1	4:1
Yellowstone River/ Forsyth	2:1	3:1	4:1	2:1
Yellowstone River/ Sidney	1:1	1:5	6:1	1:1
Mean *	1:1	1:1	18:1	1:1

*Assumes concentrations less than 0.01 mg/l TSIN and 0.001 mg/l phosphate phosphorus equal zero.

**Not determinable due to non-detectable TSIN and phosphate phosphorus

Table 20. Total soluble inorganic nitrogen ($\text{NO}_2 + \text{NO}_3\text{-N}$ plus $\text{NH}_4 + \text{NH}_3\text{-N}$) as a percentage of the recommended maximum instream level (0.35 mg/l) -- Northeast Loop

Station	Spring	Summer	Fall	Mean*
Beaver Creek/Hinsdale	37	< 6	6	14
Box Elder Creek	37	DRY	11	24
Big Muddy Creek	94	8	8	37
Big Spring Creek	260	169	209	212
Judith River/Utica	14	6	23	14
Judith River/Danvers	386	260	463	370
Judith River/Winifred	414	174	271	287
Milk River/Nashua	74	< 6	< 6	25
Missouri River/ Winifred	411	< 6	77	163
Missouri River/ Mobridge	117	< 6	< 6	39
Missouri River/ Culbertson	ICE	46	49	47
Musselshell River/ Harlowton	< 6	< 6	6	2
Musselshell River/Bundy	103	< 6	3	35
Musselshell River/ Delphia	103	< 6	3	35
Musselshell River/ Mosby	83	< 6	3	28
Poplar River	74	3	< 6	26
Redwater River/Circle	128	3	< 6	44
Redwater River/Poplar	146	< 6	< 6	48
Wolf Creek/Stanford	46	37	111	65
Wolf Creek/Denton	600	1409	214	741
Mean *	165	111	73	116

*Assumes concentrations less than 0.01 mg/l equal zero

Table 21. Total soluble inorganic nitrogen ($\text{NO}_2 + \text{NO}_3\text{-N}$ plus $\text{NH}_4 + \text{NH}_3\text{-N}$) as a percentage of the recommended maximum instream level (0.35 mg/l) -- Southeast Loop

Station	Spring	Summer	Fall	Mean*
Armell's Creek	268	14	DRY	141
Beaver Creek	211	< 6	<6	70
Bighorn River	97	51	46	65
Clark's Fork River	163	68	237	156
Little Missouri River	63	< 6	3	22
Powder River/Broadus	177	94	<6	90
Powder River/Locate	128	31	6	55
Rosebud Creek	154	26	6	62
Shields River	128	91	77	99
Tongue River/ Brandenberg	97	<6	<6	32
Tongue River/ Miles City	68	6	23	32
Yellowstone River/ Livingston	51	8	14	25
Yellowstone River/ Billings	191	46	160	132
Yellowstone River/ Huntley	160	20	63	81
Yellowstone River/ Forsyth	137	71	31	80
Yellowstone River/ Sidney	80	3	17	33
Mean *	136	33	45	72

*Assumes concentrations less than 0.01 mg/l equal zero

Table 22. Total phosphorus as a percentage of the recommended maximum instream level (0.05 mg/l) -- Northeast Loop

Station	Spring	Summer	Fall	Mean*
Beaver Creek/Hinsdale	940	260	40	413
Box Elder Creek	420	DRY	40	230
Big Muddy Creek	540	360	280	393
Big Spring Creek	220	180	80	160
Judith River/Utica	< 20	<20	<20	<20
Judith River/Danvers	440	120	60	207
Judith River/Winifred	700	160	40	300
Milk River/Nashua	1280	340	120	580
Missouri River/ Winifred	600	120	80	267
Missouri River/ Mobridge	560	140	20	240
Missouri River/ Culbertson	ICE	320	40	180
Musselshell River/ Harlowton	80	60	<20	47
Musselshell River/ Bundy	620	340	<20	320
Musselshell River/ Delphia	760	300	<20	353
Musselshell River/Mosby	1020	180	<20	400
Poplar River	640	240	<20	293
Redwater River/Circle	260	80	20	120
Redwater River/Poplar	920	DNA	<20	460
Wolf Creek/Stanford	60	40	40	47
Wolf Creek/Denton	120	80	40	80
Mean *	536	184	45	253

*Assumes concentrations less than 0.01 mg/l equal zero

Table 23. Total phosphorus as a percentage of the recommended maximum instream level (0.05 mg/l) --- Southeast Loop

Station	Spring	Summer	Fall	Mean*
Armell's Creek	140	80	DRY	110
Beaver Creek/Wibaux	340	80	20	147
Bighorn River	400	120	20	180
Clark's Fork River	700	1360	40	700
Little Missouri River	800	120	40	320
Powder River/Broadus	7400	1200	80	2893
Powder River/Locate	5200	980	40	2073
Rosebud Creek	500	400	40	313
Shields River	260	140	<20	133
Tongue River/ Brandenberg	500	140	<20	213
Tongue River/ Miles City	1160	100	<20	420
Yellowstone River/ Livingston	60	80	20	53
Yellowstone River/ Billings	280	340	60	227
Yellowstone River/ Huntley	340	140	60	180
Yellowstone River/ Forsyth	700	200	60	320
Yellowstone River/ Sidney	760	180	40	327
Mean *	1221	354	35	547

*Assumes concentrations less than 0.01 mg/l equal zero

Table 24. Un-ionized Ammonia (NH_3 as N in mg/l) -- Northeast Loop

Station	Spring	Summer	Fall	Mean
Beaver Creek/Hinsdale	< 0.01	< 0.01	< 0.01	< 0.01
Box Elder Creek	< 0.01	DRY	< 0.01	< 0.01
Big Muddy Creek	< 0.01	< 0.01	< 0.01	< 0.01
Big Spring Creek	< 0.01	< 0.01	< 0.01	< 0.01
Judith River/Utica	< 0.01	< 0.01	< 0.01	< 0.01
Judith River/Danvers	< 0.01	< 0.01	< 0.01	< 0.01
Judith River/Winifred	< 0.01	< 0.01	< 0.01	< 0.01
Milk River/Nashua	< 0.01	< 0.01	< 0.01	< 0.01
Missouri River/ Winifred	< 0.01	< 0.01	< 0.01	< 0.01
Missouri River/ Moberge	< 0.01	< 0.01	< 0.01	< 0.01
Missouri River/ Culbertson	ICE	< 0.01	< 0.01	< 0.01
Musselshell River/ Harlowton	< 0.01	< 0.01	< 0.01	< 0.01
Musselshell River/ Bundy	< 0.01	< 0.01	< 0.01	< 0.01
Musselshell River/ Delphia	< 0.01	< 0.01	< 0.01	< 0.01
Musselshell River/ Mosby	< 0.01	< 0.01	< 0.01	< 0.01
Poplar River	< 0.01	< 0.01	< 0.01	< 0.01
Redwater River/Circle	< 0.01	< 0.01	< 0.01	< 0.01
Redwater River/Poplar	< 0.01	< 0.01	< 0.01	< 0.01
Wolf Creek/Stanford	< 0.01	< 0.01	< 0.01	< 0.01
Wolf Creek/Denton	< 0.01	< 0.01	< 0.01	< 0.01
Mean	< 0.01	< 0.01	< 0.01	< 0.01



ALGAL ASSAY

Rationale

The algal assay is based on Liebig's law of the minimum, which states that "growth is limited by the substance that is present in minimal quantity with respect to the needs of the organism" (U.S.E.P.A., 1971). Algal assays are used in the biological monitoring program for the following purposes: 1) to determine the algae growing potential of stream water and 2) to determine the algae growing potential of stream water after introducing nutrients that would be present in a municipal wastewater discharge..

Methods

Algal assays were conducted following "bottle test" procedures published by the U.S. Environmental Protection Agency (Miller et al., 1978). The unicellular green alga *Selenastrum capricornutum* Printz was used as the test alga. Combined nutrient spikes consisted of 0.10 mg/l P plus 1.00 mg/l N. Three replicates were run on each treatment, i.e., control and combined nutrient spike. Maximum standing crop was measured and reported in terms of mg/l dry weight, averaged over the three replicates. Theoretical maximum standing crop (TMSC) was determined by multiplying measured ortho-P and TSIN values by the appropriate production coefficient (430 and 38, respectively) and by taking the lesser of the two resulting values. Statistical reliability of mean maximum standing crop (MMSC) as compared to theoretical maximum standing crop (TMSC) was determined from coefficient of variance criteria presented by Miller et al. (1978):

- + 50% for TMSC < 1.00 mg/l
- + 30% for TMSC > 1.00 but < 3.00 mg/l
- + 20% for TMSC > 3.00 but < 10.00 mg/l
- + 10% for TMSC > 10.00 mg/l

Low MMSC values that are significantly different could be due to: 1) micronutrients limiting; 2) something toxic or inhibitory in the water sample; and/or 3) nutrients incorrectly overestimated. High values that are significantly different could be the result of incorrectly underestimating nutrients available to the algae.

Results

Algal assay results for summer 1979 are presented in Tables 26 and 27.

Interpretation

To prepare water for algal assay analysis, samples were filtered through a 0.45 micrometer mesh membrane filter. In most cases, filtration reduced phosphate concentrations in the control water to less than the detection limit, indicating that most of the phosphate in eastern Montana waters is

associated with the particulate fraction. This also helps to explain why observed standing crops were consistently lower than theoretical standing crops; at most stations the latter were based on the detection limit for either phosphate or TSIN rather than on the actual value, which may have been significantly lower than the detection limit.

Standing crops in samples spiked with a combination of algal nutrients also were consistently lower than theoretical standing crops. The most plausible explanation for this feature is growth limitation by a shortage of micronutrients like iron or manganese, which, like phosphate, may be associated largely with the particulate fraction. Nutrients associated with the particulate fraction ultimately may be used by periphyton plants, but they will be much less readily available than dissolved nutrients.

The average control standing crop for all Northeast Loop stations (1.07 mg/l) was on a par with values for the Northcentral Loop (0.92 mg/l) and the Northwest Loop (0.99 mg/l) but significantly lower than the average value for the Southwest Loop (4.24 mg/l). The average value for the Southeast Loop stations (0.14 mg/l) was significantly lower than average values for all other loops.

Table 26. Algal Assay Results, Summer 1979 -- Northeast Loop

Station	Control		Nutrient Spike	
	Mean Maximum Standing Crop (mg/l)	Significantly Different from TMSC?	Mean Maximum Standing Crop (mg/l)	Significantly Different from TMSC?
Beaver Creek/Hinsdale	0.02	yes-low	0.26	yes-low
*Box Elder Creek	9.66	yes-high	31.00	yes-low
Big Muddy Creek	0.09	yes-low	16.92	yes-low
Big Spring Creek	9.02	yes-low	24.94	yes-low
Judith River/Utica	0.29	yes-low	15.50	yes-low
Judith River/Danvers	0.07	yes-low	22.84	yes-low
Judith River/Winifred	0.22	yes-low	22.16	yes-low
Milk River/Nashua	0.11	yes-low	17.49	yes-low
Missouri River/Winifred	0.08	yes-low	19.38	yes-low
Missouri River/Mobridge	0.09	yes-low	19.17	yes-low
Missouri River/ Culbertson	0.09	yes-low	22.38	yes-low
Musselshell River/ Harlowton	0.31	yes-low	10.91	yes-low
Musselshell River/Bundy	0.20	yes-low	6.00	yes-low
Musselshell River/ Delphia	0.37	yes-low	19.20	yes-low
Musselshell River/ Mosby	0.13	yes-low	7.90	yes-low
Poplar River	0.11	yes-low	21.03	yes-low
Redwater River/Circle	0.05	no	0.15	yes-low
Redwater River/Poplar	0.13	no	2.64	yes-low
Wolf Creek/Stanford	0.01	yes-low	18.90	yes-low
Wolf Creek/Denton	0.35	yes-low	23.87	yes-low
Mean	1.07		16.13	

*Spring sample, no flow at site on summer visit

Table 27. Algal Assay Results, Summer 1979 -- Southeast Loop

Station	Control		Nutrient Spike	
	Mean Maximum Standing Crop (mg/l)	Significantly Different from TMSC?	Mean Maximum Standing Crop (mg/l)	Significantly Different from TMSC?
Armell's Creek	0.14	no	16.50	yes-low
Beaver Creek/Wibaux	0.27	yes-high	10.04	yes-low
Bighorn River	0.24	yes-high	24.19	yes-low
Clark's Fork River	0.08	yes-low	21.69	yes-low
Little Missouri River	0.15	yes-low	19.01	yes-low
Powder River/Broadus	0.10	yes-low	*	*
Powder River/Locate	0.10	yes-low	21.62	yes-low
Rosebud Creek	0.09	yes-low	26.13	yes-low
Shields River	0.11	yes-low	11.84	yes-low
Tongue River/ Brandenberg	0.10	yes-low	23.17	yes-low
Tongue River/ Miles City	0.10	yes-low	19.34	yes-low
Yellowstone River/ Livingston	0.18	yes-low	19.70	yes-low
Yellowstone River/ Billings	0.11	yes-low	20.37	yes-low
Yellowstone River/ Huntley	0.23	yes-high	15.79	yes-low
Yellowstone River/ Forsyth	0.08	yes-low	23.26	yes-low
Yellowstone River/ Sidney	0.08	yes-low	2.80	yes-low
Mean	0.14		18.36	

*Insufficient sample

PERIPHYTON PRODUCTION

Rationale

Periphyton is the community of plants and animals, most of them microscopic, living attached to or in close proximity of the stream bottom. In terms of primary production--converting solar energy to plant biomass--it is the most important community in the majority of Montana streams.

Measuring the growth of periphyton organisms on artificial substrates placed in a stream is one method of estimating the productive potential of the stream. The two parameters most commonly measured are chlorophyll a (the most significant photosynthetic pigment) and ash-free weight or biomass. Measurements of these parameters have been made on a great variety of surface waters worldwide and in Montana. Chlorophyll accrual rates in some Montana streams have been summarized by Klarich (1976). An assessment of a stream's trophic status can be made by comparing its rate of accrual to rates in other waters known to be oligotrophic, mesotrophic or eutrophic.

The autotrophic index (AI) is the ratio of biomass to chlorophyll a. Chlorophyll a usually contributes from 1 to 2 percent of algal dry weight, resulting in AI values of 50 to 100 in pure algal cultures. As a stream is enriched with organic compounds the proportion of consuming, non-chlorophyll bearing organisms increases and the fraction of autotrophic, chlorophyll bearing organisms (algae) decreases. Unpolluted stream AI values normally range from 50 to 200. Much larger AI values indicate poor water quality (A.P.H.A., 1975).

The amount of pheophytin a in a periphyton sample relative to the amount of chlorophyll a is an indicator of the physiological condition of the algae. Pheophytin a is derived from chlorophyll a upon breakdown and loss of magnesium ion. Acidification in the laboratory has the same effect. Acidification of a solution of pure chlorophyll a results in a 40 percent reduction in optical density, yielding a before/after acidification ratio of about 1.7. Field samples with a ratio of 1.7 are considered to contain little if any pheophytin a and to be in excellent physiological condition. Solutions of pure pheophytin show no reduction in optical density upon acidification and have a before/after ratio of 1.0. Thus, mixtures of chlorophyll a and pheophytin a have optical density ratios ranging from 1.0 to 1.7 (A.P.H.A., 1975).

The ratio of yellow pigment (carotene) to green pigment (chlorophyll) in a sample of mixed algae can be used as an index of community stability and productivity (Margalef, 1969). In young, vigorously growing algal communities the green photosynthetic pigment chlorophyll a predominates and the yellow to green optical density ratio is low, usually about 2. As the community ages and becomes more diversified, yellow pigments predominate and the yellow to green ratio increases to 3 or greater (Oum, 1963).

Methods

Artificial substrates (glass microscope slides) were used to measure the accrual of periphyton pigments and biomass. The slides were placed in a plastic carriage (Periphytometer II) produced by Design Alliance, Inc. of Cincinnati, Ohio. The carriage and slides ensemble was tied to a cement cinder block, which served as an anchor. The sampling device was placed in water of moderate current velocity (0.1 to 0.5 m/sec) and moderate depth (0.3 to 1.0 m) such that the slides were oriented with their surfaces perpendicular to the direction of flow. In larger rivers, the slide carriage was placed in a floatation device provided by the manufacturer, which was tied to a bridge or some other permanent object. In such cases the slides were oriented with their surfaces parallel to the direction of flow and their top edges just below the water's surface. The slides were exposed from 13 to 28 days depending on season, water temperature, and inherent productivity.

Upon retrieval, the slides were removed from the carriage and immediately placed into light-proof slide boxes. The boxes were labeled and transferred to the laboratory on ice. On arrival at the lab, the boxes were placed in a freezer for at least 24 hours to enhance cell lysis.

Pigment extraction and measurement were performed according to the American Public Health Association (1975) with the following procedural exceptions. Periphyton was scraped into 50 ml, foil-wrapped centrifuge tubes. For each slide scraped, 10 ml of 90 percent acetone-10 percent saturated $MgCO_3$ solution was added to the tube. Usually one sample consisted of scrapings from 4 slides, consequently the total acetone volume equalled 40 ml. The tubes were placed in a sonic bath for at least 20 minutes to aid pigment extraction, then allowed to steep for at least 24 hours in the dark under refrigeration at 4°C, and sonified again for at least 20 minutes. Pigment optical density readings were made with a Perkin-Elmer Model 200 Spectrophotometer at a resolution setting of 1.0 nanometer and path length of 1.0 centimeter.

Biomass determinations were also done according to A.P.H.A. (1975) with the following variations. Biomass and chlorophyll measurements were made from the same "pooled" slide samples. Vycor 100 ml glass evaporating dishes were used. Prior to placing the samples in the drying oven, the acetone was evaporated under a bank of sun lamps.

Results

Tables 28 through 37 contain chlorophyll *a* accrual rates, biomass accrual rates, autotrophic index values, chlorophyll *a*/pheophytin *a* ratios, and carotene/chlorophyll ratios, respectively. Unfortunately, for a variety of reasons, there are many gaps in the periphyton production data for eastern Montana. A box containing most of the slides from the spring trip were removed from the laboratory freezer and inadvertently left unrefrigerated for several days, thus spoiling the samples. Ice cover or near-dry streambeds were encountered on three occasions. Fluctuating water levels and damaged or missing periphytometers accounted for the remaining gaps.

Interpretation

Chlorophyll a accrual rates in streams of eastern Montana averaged from 0.01 to 2.04 mg/m²/day. Klarich (1976) reported mean accrual values ranging from 0.7 at Laurel to 12.2 at Huntley for a reach of the Yellowstone River he describes as "mesotrophic". Ingman (1978) found accrual rates averaging 3.1 for a moderately enriched section of Prickly Pear Creek below the Helena sewage treatment plant discharge. At the other extreme, Bahls (1978) reported mean chlorophyll a accrual rates of 0.13 and 0.14 mg/m²/day for two very oligotrophic northwestern Montana streams. From these previously published data an arbitrary chlorophyll a accrual rate of 0.5 mg/m²/day can be considered transitional between oligotrophic and mesotrophic status. Applying this criterion to the eastern Montana chlorophyll a accrual rates, 24 of the 34 stations for which data are available would be classified as oligotrophic. The remaining ten stations would be classified as mesotrophic in terms of chlorophyll a accrual.

Mean biomass accrual rates in streams of eastern Montana ranged from 8 mg/m²/day in the Redwater River near Poplar to 336 mg/m²/day in the Judith River at Danvers. Klarich (1976) reported extreme values of 50 and 730 mg/m²/day in the Yellowstone River above and below Billings, respectively. Ingman (1978) reported a mean biomass accrual rate of 338 mg/m²/day for Prickly Pear Creek. Bahls (1978) found mean biomass accrual rates of 115 and 102 mg/m²/day for the two oligotrophic northwest Montana streams he studied. Whittaker (1970) has determined that normal biomass production rates for streams range from 300 to 4100 mg/m²/day. All stations in eastern Montana except the Judith River/Danvers site fell below Whittaker's lowest normal value. Twenty-seven stations were below the biomass accrual rate of 115 mg/m²/day that Bahls found on an oligotrophic stream in northwest Montana, further substantiating the oligotrophic status assigned to the majority of eastern Montana stations. The exceptions were Big Spring Creek, the Judith River at Danvers, the Musselshell River at Mosby, Wolf Creek at Stanford and Denton, the Clark's Fork River and the Yellowstone River at Huntley.

Mean autotrophic index values ranged from 75 in the Yellowstone River near Livingston to 1392 in Beaver Creek near Hinsdale. Twelve stations had mean autotrophic index values that fell below the unpolluted criterion of 200; eight additional sites had values ranging from 200 to 300 and may be considered borderline. Often the very high autotrophic index values were from stations with relatively little periphyton growth. Consequently, these high values may be due in large part to analytical error inherent in low-range biomass and chlorophyll measurements.

Mean chlorophyll a/pheophytin a ratios ranged from 1.47 to 1.80 at stations in eastern Montana with an overall mean value of about 1.62. This indicates that the physiological condition of algae colonizing artificial substrates in eastern Montana was fair to excellent.

Mean carotene/chlorophyll or "yellow/green" ratios were within the range of 1.89 to 2.89 at all sites in eastern Montana. This means that algae associations colonizing artificial substrates in eastern Montana streams are young and exhibit relatively high chlorophyll a concentrations.

Table 28. Chlorophyll a accrual (mg/m²/day) -- Northeast Loop

Station	Spring	Summer	Fall	Mean
Beaver Creek/Hinsdale	----	----	0.01	0.01
Box Elder Creek	----	DRY	----	----
Big Muddy Creek	----	0.22	0.07	0.14
Big Spring Creek	----	1.29	2.15	1.72
Judith River/Utica	0.25	0.87	0.32	0.48
Judith River/Danvers	----	0.97	3.11	2.04
Judith River/Winifred	----	0.14	0.03	0.08
Milk River/Nashua	----	----	0.07	0.07
Missouri River/Winifred	----	0.14	----	0.14
Missouri River/Mobridge	----	----	----	----
Missouri River/ Culbertson	ICE	----	0.12	0.12
Musselshell River/ Harlowton	----	0.27	0.40	0.34
Musselshell River/ Bundy	----	0.06	0.11	0.08
Musselshell River/ Delphia	----	0.04	0.04	0.04
Musselshell River/ Mosby	----	----	0.58	0.58
Poplar River	----	0.69	0.07	0.38
Redwater River/Circle	----	----	0.05	0.05
Redwater River/Poplar	----	----	0.01	0.01
Wolf Creek/Stanford	2.27	1.62	0.29	1.39
Wolf Creek/Denton	----	0.43	1.49	0.96
Mean	1.26	0.56	0.52	0.59

Table 29. Chlorophyll a accrual (mg/m²/day) -- Southeast Loop

Station	Spring	Summer	Fall	Mean
Armell's Creek	----	0.13	DRY	0.13
Beaver Creek/Wibaux	----	----	0.07	0.07
Bighorn River	----	0.53	----	0.53
Clark's Fork River	----	1.09	1.22	1.16
Little Missouri River	----	----	0.03	0.03
Powder River/Broadus	----	0.01	0.07	0.04
Powder River/Locate	----	0.01	----	0.01
Rosebud Creek	----	0.04	0.01	0.02
Shields River	----	----	0.72	0.72
Tongue River/ Brandenberg	----	0.03	0.06	0.04
Tongue River/ Miles City	----	0.67	0.09	0.38
Yellowstone River/ Livingston	----	0.72	1.74	1.23
Yellowstone River/ Billings	----	----	0.45	0.45
Yellowstone River/ Huntley	----	1.44	----	1.44
Yellowstone River/ Forsyth	----	0.15	----	0.15
Yellowstone River/ Sidney	----	----	0.32	0.32
Mean	----	0.44	0.43	0.44

Table 30. Biomass accrual (mg/m²/day) -- Northeast Loop

Station	Spring	Summer	Fall	Mean
Beaver Creek/Hinsdale	----	----	19	19
Box Elder Creek	----	DRY	----	----
Big Muddy Creek	----	81	11	46
Big Spring Creek	----	138	176	157
Judith River/Utica	49	158	86	98
Judith River/Danvers	----	113	559	336
Judith River/Winifred	----	27	13	20
Milk River/Nashua	----	----	27	27
Missouri River/ Winifred	----	20	----	20
Missouri River/ Mobridge	----	----	----	----
Missouri River/ Culbertson	ICE	----	24	24
Musselshell River/ Harlowton	----	51	88	70
Musselshell River/ Bundy	----	14	71	42
Musselshell River/ Delphia	----	12	28	20
Musselshell River/ Mosby	----	----	141	141
Poplar River	----	123	18	70
Redwater River/Circle	----	----	11	11
Redwater River/Poplar	----	----	8	8
Wolf Creek/Stanford	291	221	76	196
Wolf Creek/Denton	----	112	202	157
Mean	170	89	92	96

Table 31. Biomass accrual (mg/m²/day) -- Southeast Loop

Station	Spring	Summer	Fall	Mean
Armell's Creek	----	42	DRY	42
Beaver Creek/Wibaux	----	----	28	28
Bighorn River	----	42	----	42
Clark's Fork River	----	131	134	132
Little Missouri River	----	----	23	23
Powder River/Broadus	----	6	25	16
Powder River/Locate	----	9	----	9
Rosebud Creek	----	16	11	14
Shields River	----	----	62	62
Tongue River/ Brandenberg	----	16	26	21
Tongue River/ Miles City	----	103	19	61
Yellowstone River/ Livingston	----	60	115	88
Yellowstone River/ Billings	----	----	96	96
Yellowstone River/ Huntley	----	197	----	197
Yellowstone River/ Forsyth	----	21	----	21
Yellowstone River/ Sidney	----	----	63	63
Mean	----	58	55	57

Table 32. Autotrophic Index - Northeast Loop

Station	Spring	Summer	Fall	Mean
Beaver Creek/Hinsdale	----	----	1392	1392
Box Elder Creek	----	DRY	----	----
Big Muddy Creek	----	371	148	260
Big Spring Creek	----	116	82	99
Judith River/Utica	201	181	281	221
Judith River/Danvers	----	117	180	148
Judith River/Winifred	----	195	538	366
Milk River/Nashua	----	----	390	390
Missouri River/Winifred	----	141	----	141
Missouri River/Mobridge	----	----	----	----
Missouri River/ Culbertson	ICE	----	208	208
Musselshell River/ Harlowton	----	189	223	206
Musselshell River/ Bundy	----	237	693	465
Musselshell River/ Delphia	----	351	643	497
Musselshell River/ Mosby	----	----	244	244
Poplar River	----	180	276	228
Redwater River/Circle	----	----	213	213
Redwater River/Poplar	----	----	731	731
Wolf Creek/Stanford	131	137	263	177
Wolf Creek/Denton	----	261	132	196
Mean	166	206	390	305

Table 33. Autotrophic Index -- Southeast Loop

Station	Spring	Summer	Fall	Mean
Armell's Creek	----	323	DRY	323
Beaver Creek/Wibaux	----	----	423	423
Bighorn River	----	85	----	85
Clark's Fork River	----	120	110	115
Little Missouri River	----	----	803	803
Powder River/Broadus	----	1588	348	968
Powder River/Locate	----	1191	----	1191
Rosebud Creek	----	428	1500	964
Shields River	----	----	88	88
Tongue River/ Brandenberg	----	611	448	530
Tongue River/ Miles City	----	155	203	358
Yellowstone River/ Livingston	----	84	66	75
Yellowstone River/ Billings	----	----	226	226
Yellowstone River/ Huntley	----	136	----	136
Yellowstone River/ Forsyth	----	171	----	171
Yellowstone River/ Sidney	----	----	193	193
Mean	-----	445	401	423

Table 34. Chlorophyll a/Pheophytin a ratio -- Northeast Loop

Station	Spring	Summer	Fall	Mean
Beaver Creek/Hinsdale	----	----	1.47	1.47
Box Elder Creek	----	DRY	----	----
Big Muddy Creek	-----	1.70	1.61	1.66
Big Spring Creek	----	1.62	1.58	1.60
Judith River/Utica	1.71	1.65	1.57	1.64
Judith River/Danvers	----	1.67	1.51	1.59
Judith River/Winifred	----	1.68	1.58	1.63
Milk River/Nashua	----	----	1.57	1.57
Missouri River/ Winifred	----	1.69	----	1.69
Missouri River/ Moberg	----	----	----	----
Missouri River/ Culbertson	ICE	----	1.66	1.66
Musselshell River/ Harlowton	----	1.61	1.58	1.60
Musselshell River/ Bundy	----	1.61	1.63	1.62
Musselshell River/ Delphia	----	1.77	1.63	1.70
Musselshell River/ Mosby	----	----	1.60	1.60
Poplar River	----	1.57	1.60	1.58
Redwater River/Circle	----	----	1.58	1.58
Redwater River/Poplar	----	----	1.63	1.63
Wolf Creek/Stanford	1.75	1.61	1.58	1.65
Wolf Creek/Denton	----	1.56	1.56	1.56
Mean	1.73	1.64	1.58	1.62

Table 35. Chlorophyll a/Pheophytin a ratio -- Southeast Loop

Station	Spring	Summer	Fall	Mean
Armell's Creek	----	1.55	DRY	1.55
Beaver Creek/Wibaux	----	----	1.53	1.53
Bighorn River	----	1.70	----	1.70
Clark's Fork River	----	1.61	1.61	1.61
Little Missouri River	----	----	1.48	1.48
Powder River/Broadus	----	2.00	1.61	1.80
Powder River/Locate	----	1.69	----	1.69
Rosebud Creek	----	1.66	----	1.66
Shields River	----	----	1.65	1.65
Tongue River/ Brandenberg	----	1.68	1.61	1.64
Tongue River/ Miles City	----	1.65	1.64	1.64
Yellowstone River/ Livingston	----	1.65	1.51	1.58
Yellowstone River/ Billings	----	----	1.60	1.60
Yellowstone River/ Huntley	----	1.58	----	1.58
Yellowstone River/ Forsyth	----	1.67	----	1.67
Yellowstone River/ Sidney	----	----	1.62	1.62
Mean	----	1.68	1.59	1.63

Table 36. Carotene/Chlorophyll ratio (OD430/OD663) -- Northeast Loop

Station	Spring	Summer	Fall	Mean
Beaver Creek/Hinsdale	----	----	2.89	2.89
Box Elder Creek	----	DRY	----	----
Big Muddy Creek	----	1.98	2.32	2.15
Big Spring Creek	----	1.92	2.17	2.04
Judith River/Utica	2.03	2.06	1.99	2.03
Judith River/Danvers	----	2.00	2.29	2.14
Judith River/Winifred	----	2.02	1.94	1.98
Milk River/Nashua	----	----	2.10	2.10
Missouri River/ Winifred	----	1.89	----	1.89
Missouri River/ Moberg	----	----	----	----
Missouri River/ Culbertson	ICE	----	2.09	2.09
Missouri River/ Harlowton	----	2.18	1.88	2.03
Musselshell River/ Bundy	----	2.44	2.17	2.30
Musselshell River/ Delphia	----	2.30	2.20	2.25
Musselshell River/ Mosby	----	----	2.30	2.30
Poplar River	----	2.08	2.07	2.08
Redwater River/Circle	----	----	2.25	2.25
Redwater River/Poplar	----	----	2.77	2.77
Wolf Creek/Stanford	1.95	2.17	2.00	2.04
Wolf Creek/Denton	----	2.09	2.11	2.10
Mean	1.99	2.09	2.21	2.15

Table 37. Carotene/Chlorophyll ratio (OD430/OD663) -- Southeast Loop

Station	Spring	Summer	Fall	Mean
Armell's Creek	----	2.32	DRY	2.32
Beaver Creek/Wibaux	----	----	2.07	2.07
Bighorn River	----	2.34	----	2.34
Clark's Fork River	----	2.22	2.17	2.20
Little Missouri River	----	----	2.19	2.19
Powder River/Broadus	----	3.17	1.96	2.56
Powder River/Locate	----	2.25	----	2.25
Rosebud Creek	----	2.23	----	2.23
Shields River	----	----	2.09	2.09
Tongue River/ Brandenberg	----	2.40	2.19	2.30
Tongue River/ Miles City	----	2.06	2.13	2.10
Yellowstone River/ Livingston	----	2.11	2.21	2.16
Yellowstone River/ Billings	----	----	2.23	2.23
Yellowstone River/ Huntley	----	2.29	----	2.29
Yellowstone River/ Forsyth	----	2.07	----	2.07
Yellowstone River/ Sidney	----	----	2.19	2.19
Mean	----	2.31	2.14	2.23



PERIPHYTON COMMUNITY STRUCTURE

Rationale

Except in the lower reaches of our largest rivers--the Kootenai, Clark Fork, Missouri, and Yellowstone--the stream periphyton (bottom) community is more important than the stream plankton (open water) community in terms of plant diversity and plant production.

In unpolluted waters, the dominant periphyton plants are diatoms. Diatoms are microscopic, golden-brown algae encased in silica. They are a sign of good river health. Moreover, they are the preferred food of many aquatic invertebrates.

When a river is polluted and its chemical and biological equilibrium is disturbed, diatoms are often displaced by coarser, less palatable green and blue-green algae (Patrick, 1978). In Montana streams, this take-over is usually accomplished by the long, filamentous green alga *Cladophora*, which often becomes a nuisance. For this reason we have ranked diatoms relative to other significant algae as a rough index of stream well-being. Theoretically, the lower diatoms are ranked, the more polluted and unbalanced is the river. It should be noted that some non-diatom algae may be seasonally very abundant in nearly pristine streams, for example the blue-green alga *Nostoc*.

Clean waters usually have many different species of diatoms with some fairly common but with none really dominant. Polluted waters have fewer species, often with one or two species very abundant. Clean water is said to have high diversity and polluted water is said to have low diversity. Diversity can be measured simply by counting the number of species in a sample or by calculating a rather involved formula called a diversity index. The most widely accepted diversity index is the Shannon-Weaver Index or $\bar{d}$. Bahls (1979) found that benthic diatom associations in unpolluted Montana streams usually had more than 25 species and $\bar{d}$ values greater than 3. Species numbers significantly less than 25 and diversity values significantly below 3 may be indicative of pollution.

Methods

Periphytic algae were collected from natural substrates on the stream bottom. Quantities of larger, macroscopic species were picked in proportion to their abundance relative one to one another and to the attached diatom (slime) community as a whole. Accordingly, an appropriate amount of the diatom community was collected by scraping rocks and other submerged substrates with a razor blade, pocket knife or scalpel. Different substrates were scraped in proportion to the area they covered. An effort also was made to collect algae from both pools and riffles, again in proportion to the extent these stream features prevailed at a given site. The ultimate objective was to obtain a sample of algae that was a miniature replicate of the stream's periphyton community. Samples were preserved with Lugol's (IKI) solution and returned to the lab for analyses.

Conspicuous non-diatom algae were removed, examined microscopically, and identified to genus. The relative abundance and rank of each significant non-diatom genus and the diatom community as a whole were then recorded. A portion of the diatom community was used to prepare a permanent, randomly strewn mount using sulfuric acid and potassium dichromate as the oxidizing agents and Cargille's "Carmount-165" as the mounting medium (A.P.H.A., 1975). A diatom species proportional count was performed on each slide following the technique outlined by Weber (1973), except that in excess of 300 rather than 250 cells were tallied. The results were used to compute percent relative abundance of taxa and diatom species diversity using the Shannon-Weaver formula recommended by Weber (1973):

$$\bar{d} = \frac{C}{N} (N \log_{10} N - \sum n_i \log_{10} n_i)$$

where C = 3.321928; N = total number of individuals; and n_i = number of individuals in the i th species.

Results

Parameters depicting periphyton community structure are presented in Tables 38 through 43.

Interpretation

Diatoms occurred in all samples collected in eastern Montana and ranked number one in 40 percent of those samples. The only significant non-diatom alga was *Cladophora*, which occurred in 64 percent of the samples and ranked number one in 35 percent. The green alga *Spirogyra*, an indicator of eutrophic conditions, was seasonally dominant in periphyton samples from Wolf Creek at Denton, Beaver Creek at Wibaux and the Tongue River at Miles City.

Mean number of diatom species and mean diatom species diversity values all exceeded the criteria below which pollution would be suspected, except for the Judith River at Danvers. A few sites, including Big Spring Creek, Wolf Creek at Denton and the Yellowstone River at Billings, had borderline values indicating marginal conditions.

Table 38. Estimated rank of diatoms and other significant algae by volume -- Northeast Loop

Station	Spring	Summer	Fall
Beaver Creek/Hinsdale	1. Diatoms	1. <i>Cladophora</i> 2. <i>Spirogyra</i> 3. <i>Aulosira</i> 4. Diatoms 5. <i>Oscillatoria</i> 6. <i>Anabaena</i> 7. <i>Phormidium</i>	1. <i>Cladophora</i> 2. <i>Nostoc</i> 3. Diatoms 4. <i>Phormidium</i>
Box Elder Creek	1. <i>Phormidium</i> 2. Diatoms	1. <i>Oscillatoria</i> 2. <i>Anabaena</i> 3. Diatoms 4. <i>Spirulina</i>	NS
Big Muddy Creek	NS	1. <i>Anabaena</i> 2. <i>Oedogonium</i> 3. Diatoms	1. <i>Cladophora</i> 2. Diatoms 3. <i>Phormidium</i> 4. <i>Calothrix</i>
Big Spring Creek	1. Diatoms 2. <i>Cladophora</i> 3. <i>Phormidium</i> 4. <i>Hydrurus</i>	1. <i>Cladophora</i> 2. Diatoms 3. <i>Oscillatoria</i> 4. <i>Lyngbya</i> 5. <i>Phormidium</i>	1. Diatoms 2. <i>Cladophora</i> 3. <i>Oscillatoria</i> 4. <i>Phormidium</i>
Judith River/Utica	1. Diatoms 2. <i>Hydrurus</i> 3. <i>Bumilleria</i> 4. <i>Cladophora</i> 5. <i>Audouinella</i> 6. <i>Phormidium</i>	1. <i>Oscillatoria</i> 2. <i>Cladophora</i> 3. Diatoms 4. <i>Oedogonium</i> 5. <i>Phormidium</i> 6. <i>Chaetophora</i>	1. <i>Oscillatoria</i> 2. <i>Spirogyra</i> 3. <i>Chaetophora</i> 4. Diatoms 5. <i>Cladophora</i> 6. <i>Cosmarium</i> 7. <i>Mougeotia</i> 8. <i>Closterium</i>
Judith River/Danvers	1. <i>Cladophora</i> 2. Diatoms 3. <i>Phormidium</i>	1. Diatoms 2. <i>Cladophora</i> 3. <i>Cosmarium</i> 4. <i>Oscillatoria</i> 5. <i>Lyngbya</i>	1. Diatoms 2. <i>Cladophora</i> 3. <i>Oscillatoria</i>
Judith River/Winifred	1. Diatoms 2. <i>Audouinella</i> 3. <i>Cladophora</i>	1. <i>Cladophora</i> 2. Diatoms 3. <i>Tetraspora</i> 4. <i>Cosmarium</i> 5. <i>Oscillatoria</i> 6. <i>Audouinella</i> 7. <i>Stigeoclonium</i> 8. <i>Scenedesmus</i>	1. <i>Cladophora</i> 2. Diatoms 3. <i>Spirogyra</i>

Table 38. (Continued)

Station	Spring	Summer	Fall
Milk River/Nashua	NS	1. Diatoms	1. <i>Audouinella</i> 2. Diatoms
Missouri River/ Winifred	1. Diatoms	1. <i>Cladophora</i> 2. Diatoms 3. <i>Oscillatoria</i> 4. <i>Anabaena</i>	1. Diatoms 2. <i>Cladophora</i> 3. <i>Oscillatoria</i> 4. <i>Spirulina</i>
Missouri River/ Mobridge	NS	1. <i>Cladophora</i> 2. Diatoms 3. <i>Anabaena</i> 4. <i>Scenedesmus</i>	1. <i>Cladophora</i> 2. Diatoms 3. <i>Closterium</i>
Missouri River/ Culbertson	NS	1. Diatoms 2. <i>Ulothrix</i> 3. <i>Oscillatoria</i>	1. <i>Cladophora</i> 2. Diatoms 3. <i>Oscillatoria</i> 4. <i>Audouinella</i> 5. <i>Stigeoclonium</i>
Musselshell River/ Harlowton	1. Diatoms 2. <i>Cladophora</i>	1. <i>Cladophora</i> 2. Diatoms 3. <i>Closterium</i> 4. <i>Oscillatoria</i> 5. <i>Phormidium</i>	1. Diatoms 2. <i>Cladophora</i> 3. <i>Phormidium</i>
Musselshell River/ Bundy	1. Diatoms	1. <i>Anabaena</i> 2. Diatoms	1. <i>Cladophora</i> 2. Diatoms 3. <i>Audouinella</i> 4. <i>Phormidium</i>
Musselshell River/ Delphia	1. Diatoms	1. <i>Cladophora</i> 2. <i>Phormidium</i> 3. Diatoms	1. <i>Cladophora</i> 2. <i>Spirogyra</i> 3. Diatoms 4. <i>Calothrix</i> 5. <i>Phormidium</i>
Musselshell River/ Mosby	1. Diatoms	1. <i>Phormidium</i> 2. Diatoms	1. Diatoms 2. <i>Scenedesmus</i>
Poplar River	NS	1. <i>Rhizoclonium</i> 2. Diatoms 3. <i>Phormidium</i> 4. <i>Oedogonium</i> 5. <i>Oscillatoria</i> 6. <i>Calothrix</i> 7. <i>Anabaena</i>	1. <i>Oscillatoria</i> 2. <i>Audouinella</i> 3. Diatoms 4. <i>Scenedesmus</i> 5. <i>Mougeotia</i> 6. <i>Phormidium</i> 7. <i>Dactylococcopsis</i> 8. <i>Merismopedia</i>

Table 38. (Continued)

Station	Spring	Summer	Fall
Redwater River/Circle	1. Diatoms 2. <i>Phormidium</i>	1. <i>Oedogonium</i> 2. Diatoms 3. <i>Calothrix</i> 4. <i>Bulbochaete</i> 5. <i>Oscillatoria</i>	1. <i>Rivularia</i> 2. Diatoms 3. <i>Oscillatoria</i> 4. <i>Anabaena</i>
Redwater River/Poplar	NS	1. <i>Oscillatoria</i> 2. Diatoms 3. <i>Spirulina</i> 4. <i>Calothrix</i>	1. Diatoms 2. <i>Oscillatoria</i> 3. <i>Spirulina</i>
Wolf Creek/Stanford	1. <i>Hydrurus</i> 2. Diatoms 3.	1. <i>Cladophora</i> 2. <i>Oscillatoria</i> 3. Diatoms	1. <i>Oscillatoria</i> 2. <i>Draparnaldia</i> 3. Diatoms 4. <i>Cladophora</i>
Wolf Creek/Denton	1. Diatoms 2. <i>Bumilleria</i>	1. <i>Spirogyra</i> 2. <i>Cladophora</i> 3. Diatoms 4. <i>Scenedesmus</i> 5. <i>Enteromorpha</i> 6. <i>Cosmarium</i> 7. <i>Closterium</i> 8. <i>Pediastrum</i> 9. <i>Oscillatoria</i>	1. <i>Cladophora</i> 2. Diatoms 3. <i>Scenedesmus</i> 4. <i>Cosmarium</i>
NS: No sample (sample not collected because of high flow or dry streambed or ice cover)			

Table 39. Estimated rank of diatoms and other significant algae by volume -- Southeast Loop

Station	Spring	Summer	Fall
Armell's Creek	1. Diatoms 2. <i>Phormidium</i>	1. <i>Cladophora</i> 2. <i>Lyngbya</i> 3. Diatoms 4. <i>Oedogonium</i> 5. <i>Phormidium</i>	1. <i>Chara</i> 2. <i>Lyngbya</i> 3. <i>Vaucheria</i> 4. Diatoms 5. <i>Gloeocystis</i> 6. <i>Euglena</i>
Beaver Creek/Wibaux	1. Diatoms 2. <i>Spirogyra</i> 3. <i>Oedogonium</i> 4. <i>Phormidium</i> 5. <i>Audouinella</i>	1. <i>Cladophora</i> 2. Diatoms	1. <i>Spirogyra</i> 2. <i>Microspora</i> 3. Diatoms 4. <i>Mougeotia</i>
Bighorn River	1. Diatoms 2. <i>Cladophora</i> 3. <i>Phormidium</i>	1. <i>Cladophora</i> 2. <i>Spirogyra</i> 3. Diatoms 4. <i>Phormidium</i>	1. <i>Cladophora</i> 2. Diatoms 3. <i>Audouinella</i> 4. <i>Stigeoclonium</i> 5. <i>Phormidium</i>
Clark's Fork River	1. <i>Cladophora</i> 2. Diatoms	1. Diatoms 2. <i>Cladophora</i> 3. <i>Oscillatoria</i> 4. <i>Phormidium</i> 5. <i>Cosmarium</i>	1. Diatoms 2. <i>Cladophora</i> 3. <i>Cosmarium</i> 4. <i>Oscillatoria</i>
Little Missouri River	NS	1. <i>Cladophora</i> 2. <i>Phormidium</i> 3. Diatoms 4. <i>Ulothrix</i>	1. <i>Calothrix</i> 2. Diatoms 3. <i>Anabaena</i> 4. <i>Oscillatoria</i>
Powder River/Broadus	1. Diatoms	1. Diatoms	1. <i>Vaucheria</i> 2. Diatoms
Powder River/Locate	1. Diatoms	1. <i>Oscillatoria</i> 2. <i>Euglena</i> 3. Diatoms	1. Diatoms 2. <i>Oscillatoria</i> 3. <i>Anabaena</i>
Rosebud Creek	1. <i>Cladophora</i> 2. Diatoms	1. <i>Cladophora</i> 2. Diatoms	1. <i>Cladophora</i> 2. <i>Audouinella</i> 3. Diatoms
Shields River	1. Diatoms 2. <i>Hydrurus</i> 3. <i>Cladophora</i>	1. <i>Cladophora</i> 2. Diatoms 3. <i>Phormidium</i> 4. <i>Closterium</i>	1. Diatoms 2. <i>Cladophora</i> 3. <i>Closterium</i> 4. <i>Ulothrix</i> 5. <i>Phormidium</i> 6. <i>Stigeoclonium</i>

Table 39. (Continued)

Station	Spring	Summer	Fall
Tongue River/ Brandenberg	1. <i>Cladophora</i> 2. <i>Audouinella</i> 3. Diatoms	1. <i>Cladophora</i> 2. <i>Spirogyra</i> 3. Diatoms 4. <i>Anabaena</i> 5. <i>Phormidium</i> 6. <i>Cosmarium</i>	1. <i>Cladophora</i> 2. <i>Audouinella</i> 3. Diatoms 4. <i>Phormidium</i>
Tongue River/Miles City	NS	1. <i>Spirogyra</i> 2. Diatoms 3. <i>Cladophora</i> 4. <i>Anabaena</i> 5. <i>Audouinella</i> 6. <i>Cosmarium</i>	1. <i>Cladophora</i> 2. <i>Spirogyra</i> 3. Diatoms 4. <i>Scenedesmus</i>
Yellowstone River/ Livingston	1. Diatoms 2. <i>Hydrurus</i> 3. <i>Cladophora</i> 4. <i>Ulothrix</i>	1. <i>Enteromorpha</i> 2. <i>Cladophora</i> 3. Diatoms 4. <i>Oscillatoria</i> 5. <i>Ulothrix</i> 6. <i>Phormidium</i>	1. Diatoms 2. <i>Enteromorpha</i> 3. <i>Cladophora</i> 4. <i>Ulothrix</i> 5. <i>Cosmarium</i> 6. <i>Scenedesmus</i> 7. <i>Oscillatoria</i>
Yellowstone River/ Billings	1. <i>Cladophora</i> 2. Diatoms	1. Diatoms 2. <i>Cladophora</i> 3. <i>Phormidium</i> 4. <i>Stigeoclon</i> 5. <i>Oscillatoria</i>	1. Diatoms 2. <i>Cladophora</i> 3. <i>Oscillatoria</i> 4. <i>Phormidium</i> 5. <i>Cosmarium</i>
Yellowstone River/ Huntley	1. Diatoms 2. <i>Cladophora</i> 3. <i>Phormidium</i> 4. <i>Stigeoclonium</i>	1. Diatoms 2. <i>Cladophora</i> 3. <i>Phormidium</i> 4. <i>Stigeoclonium</i> 5. <i>Cosmarium</i>	1. Diatoms 2. <i>Cladophora</i> 3. <i>Stigeoclonium</i> 4. <i>Oscillatoria</i>
Yellowstone River/ Forsyth	1. Diatoms 2. <i>Cladophora</i> 3. <i>Phormidium</i>	1. <i>Cladophora</i> 2. Diatoms 3. <i>Phormidium</i>	1. <i>Cladophora</i> 2. Diatoms 3. <i>Closterium</i> 4. <i>Cosmarium</i> 5. <i>Phormidium</i>

Table 39. (Continued)

Station	Spring	Summer	Fall
Yellowstone River/ Sidney	NS	1. <i>Anabaena</i> 2. Diatoms 3. <i>Oscillatoria</i> 4. <i>Phormidium</i>	1. Diatoms 2. <i>Cladophora</i> 3. <i>Spirogyra</i> 4. <i>Cosmarium</i> 5. <i>Closterium</i> 6. <i>Scenedesmus</i>
NS: No sample (sample not collected because of high flow or dry streambed)			

Table 40. Number of diatom species in the Northeast Loop.

Station	Spring	Summer	Fall	Mean
Beaver Creek/Hinsdale	NC	45	57	51
Box Elder Creek	11	54	NS	32
Big Muddy Creek	NS	42	43	42
Big Spring Creek	22	31	24	26
Judith River/Utica	25	36	25	29
Judith River/Danvers	27	37	26	30
Judith River/Winifred	17	34	38	30
Milk River/Nashua	NS	23	40	32
Missouri River/Winifred	23	62	46	44
Missouri River/Mobridge	NS	54	58	56
Missouri River/Culbertson	NS	50	41	46
Musselshell River/Harlowton	34	53	35	41
Musselshell River/Bundy	NC	61	51	56
Musselshell River/Delphia	NC	36	31	34
Musselshell River/Mosby	NC	26	46	36
Poplar River	NS	67	85	76
Redwater River/Circle	52	48	55	52
Redwater River/Poplar	NS	40	30	35
Wolf Creek/Stanford	39	26	47	37
Wolf Creek/Denton	20	44	27	30
Mean	27	43	42	37

NC: NO COUNT (Diatoms too sparse to count)

NS: NO SAMPLE (Sample not collected because of high flow or dry streambed or ice cover)

Table 41. Number of diatom species in the Southeast Loop.

Station	Spring	Summer	Fall	Mean
Armell's Creek	54	40	29	41
Beaver Creek/Wibaux	52	66	82	67
Bighorn River	25	45	34	35
Clark's Fork River	31	33	34	33
Little Missouri River	NS	40	55	48
Powder River/Broadus	30	52	53	45
Powder River/Locate	NC	62	44	53
Rosebud Creek	41	36	37	38
Shields River	34	34	36	35
Tongue River/Brandenberg	20	57	50	42
Tongue River/Miles City	NS	57	41	49
Yellowstone River/Livingston	47	50	50	49
Yellowstone River/Billings	42	31	40	38
Yellowstone River/Huntley	21	40	36	32
Yellowstone River/Forsyth	36	46	50	44
Yellowstone River/Sidney	NS	66	46	56
Mean	36	47	45	43

NC: NO COUNT (Diatoms too sparse to count)

NS: NO SAMPLE (Sample not collected because of high flow or dry streambed)

Table 42. Diatom species diversity ($\bar{d}$) in the Northeast Loop.

Station	Spring	Summer	Fall	Mean
Beaver Creek/Hinsdale	NC	3.95	4.77	4.36
Box Elder Creek	1.67	4.76	NS	3.22
Big Muddy Creek	NS	4.26	3.95	4.10
Big Spring Creek	2.97	3.72	2.71	3.14
Judith River/Utica	2.79	3.74	2.87	3.13
Judith River/Danvers	2.54	3.68	2.70	2.97
Judith River/Winifred	2.59	2.55	4.00	3.05
Milk River/Nashua	NS	3.92	3.62	3.77
Missouri River/Winifred	1.76	4.25	3.30	3.10
Missouri River/Mobridge	NS	4.08	4.74	4.41
Missouri River/Culbertson	NS	3.92	3.97	3.94
Musselshell River/Harlowton	3.94	4.85	2.59	3.79
Musselshell River/Bundy	NC	4.90	4.43	4.66
Musselshell River/Delphia	NC	4.33	3.58	4.09
Musselshell River/Mosby	NC	2.68	3.62	3.15
Poplar River	NS	4.60	5.80	5.20
Redwater River/Circle	4.71	4.21	4.42	4.45
Redwater River/Poplar	NS	3.73	2.72	3.22
Wolf Creek/Stanford	3.61	3.40	3.92	3.64
Wolf Creek/Denton	1.89	4.01	3.27	3.06
Mean	2.85	3.98	3.74	3.52

NC: NO COUNT (Diatoms too sparse to count)

NS: NO SAMPLE (Sample not collected because of high flow or dry streambed or ice cover)

Table 43. Diatom species diversity ($\bar{d}$) in the Southeast Loop.

Station	Spring	Summer	Fall	Mean
Armell's Creek	4.48	4.01	3.08	3.86
Beaver Creek/Wibaux	4.19	4.86	5.25	4.77
Bighorn River	3.55	4.45	3.67	3.89
Clark's Fork River	3.70	3.87	3.11	3.56
Little Missouri River	NS	4.05	4.80	4.42
Powder River/Broadus	2.98	4.73	4.88	4.20
Powder River/Locate	NC	4.78	3.88	4.33
Rosebud Creek	4.54	2.98	4.22	3.91
Shields River	4.08	3.97	2.68	3.58
Tongue River/Brandenberg	2.44	4.09	4.31	3.61
Tongue River/Miles City	NS	3.98	2.98	3.48
Yellowstone River/Livingston	4.31	4.49	4.88	4.56
Yellowstone River/Billings	2.31	2.70	4.17	3.06
Yellowstone River/Huntley	3.12	3.36	3.54	3.34
Yellowstone River/Forsyth	3.79	4.37	4.31	4.16
Yellowstone River/Sidney	NS	3.44	4.56	4.00
Mean	3.62	4.01	4.02	3.88

NC: NO COUNT (Diatoms too sparse to count)

NS: NO SAMPLE (Sample not collected because of high flow or dry streambed)

MACROINVERTEBRATE COMMUNITY STRUCTURE

Rationale

Macroinvertebrates comprise the energy link between periphyton and fish. They include detritus feeders, parasites, scavengers, grazers, and predators. Most organisms in this community of bottom dwellers are immature insect forms. As with the periphyton, benthic macroinvertebrates are differentially tolerant to pollution. Because of their limited mobility and relatively long life span (up to three years in some species) the invertebrates, like some periphyton, reflect water quality conditions of the recent past.

Of the common aquatic insects in Montana streams, three groups (orders) are generally used as indicators of waters with little organic pollution or oxygen-demanding wastes. These are the stoneflies (Plecoptera), mayflies (Ephemeroptera), and caddisflies (Trichoptera). Two other groups--the true flies (Diptera) and beetles (Coleoptera)--each contain species that prefer, are indifferent to, or are completely intolerant of pollution. The remaining common group of aquatic insects, the true bugs (Hemiptera), is generally considered tolerant of organic pollution. Although water quality preferences for many stream insects are not known, the relative abundance of organisms in these various groups gives a good approximation of water quality conditions.

In the typical unstressed situation, there should be a large number of taxa with few individuals in each one. This instance gives a high diversity value, emphasizing good quality water and habitat availability. Stressed waters generally have few taxa with one or two dominant. The number of macroinvertebrate taxa and macroinvertebrate diversity are considered good estimators of community health. Wilhm (1970) reported clean waters to have from 11 to 54 species and Shannon-Weaver diversity values from 2.6 to over 4. On the other hand, polluted streams have diversity values less than 2 and frequently less than 1. From our experience, unpolluted streams with favorable substrate, oxygen levels, and temperature generally produce a minimum of 15 genera and often between 20 and 30 genera and higher depending on stream order and season of collection. Diversities computed from samples of less than 100 organisms should be interpreted with caution (Weber, 1973) as such samples may not be statistically reliable.

The number of individual organisms collected may also indicate relative productivity and/or habitat availability, assuming about the same amount of effort went into each collection.

Methods

The technique used for macroinvertebrate collection is a modification of the "unit effort traveling kick" method described by Kinney et al (1978). The

objective is to sample each type of habitat while applying a similar amount of effort at each station. Where macroinvertebrates are scarce, additional effort may be required in order to collect a statistically significant number of specimens.

Equipped with a long-handled D-frame aquatic net (Ward's 10W0620)*, the sampler works all the major habitat types--riffles, pools, submerged vegetation, etc.--by dislodging organisms with his feet and capturing them as they drift downstream. Research has shown this method to have better statistical reproducibility than artificial substrate and Surber samplers in semi-arid regions where the fauna tends to be patchy and sparse (Hornig and Pollard, 1978).

When an adequate number of insects has been collected, the sampler randomly selects 100 or more specimens from the net and places them in a small jar filled one-third full of water. (At some sites 100 organisms cannot be collected in a reasonable length of time, even with additional effort.) Care is taken not to be biased by size of the organism. The jar is then filled with 95 percent ethanol, labeled, and returned to the laboratory for analysis. A few drops of glycerine are added if extended storage is required.

Organisms were identified to genus wherever possible. Enumeration results were used to compute the percent relative abundance of individuals in major pollution sensitivity groups (orders). Shannon-Weaver diversity was calculated in the same fashion as it was for the diatoms (See "PERIPHYTON COMMUNITY STRUCTURE -- Methods ").

Results

Macroinvertebrate community parameters for the Northeast and Southeast loops are presented in Tables 44 through 51.

Various problems were encountered in obtaining statistically reliable numbers (>100) of insects in a reasonable period of time at practically all stations on at least one of the three visits. Reasons included ice cover, flood conditions, and dewatering with its attendant effects of reduced current velocity, elevated temperature, and increased sedimentation. Natural channel morphology and substrate composition also presented sampling problems at certain sites.

Interpretation

Generally, streams that were sampled at more than one station had higher numbers of taxa and higher diversity values nearer the headwaters than in the

*Approximately 21.5 meshes per inch with 1 mm openings

downstream reaches. This held true for the Judith, Missouri, Musselshell, Tongue and Yellowstone rivers.

Twenty-five of the 36 stations had in excess of 15 total taxa collected while 15 of the stations had in excess of 20 taxa collected. No macroinvertebrates were found at the Missouri River station near Culbertson due to the deep channel configuration and the shifting sand substrate. In the future, artificial substrates may be considered for use on streams of this type, including Big Muddy Creek, the Missouri, Powder, Poplar and Little Missouri rivers, and the lower reaches of the Milk, Redwater, and Yellowstone rivers.

Coincidentally, most of the stations mentioned in the last paragraph were the ones that did not have at least 70 percent of the organisms collected in the three pollution intolerant groups (stoneflies, mayflies, and caddisflies). Twenty-five of the 36 stations did surpass the 70 percent value and of these 21 had mean diversity values that ranged from 2.12 to 3.65, indicating good to excellent conditions. The remaining four stations had mean diversity values that were less than 2.12 but greater than 1.35. These low diversity values may have been in part the result of relatively low individual counts.

Table 44. Mean percent relative abundance of insects in the major macroinvertebrate orders -- Northeast Loop

Station	Plecoptera (stoneflies)	Ephemeroptera (mayflies)	Trichoptera (caddisflies)	Diptera (true flies)	Hemiptera (true bugs)
Beaver Creek/Hinsdale	0	42	41	18	0
Box Elder Creek	0	6	33	56	6
Big Muddy Creek	0	0	0	10	88
Big Spring Creek	19	37	30	11	0
Judith River/Utica	30	40	23	8	0
Judith River/Danvers	17	46	26	11	0
Judith River/Winifred	12	50	11	27	0
Milk River/Nashua	0	0	0	0	100
Missouri River/ Winifred	15	63	13	8	0
Missouri River/ Moberge	<5	78	19	<5	<5
Missouri River/ Culbertson	0	0	0	0	0
Musselshell River/ Harlowton	13	60	12	13	0
Musselshell River/ Bundy	<5	59	24	6	<5
Musselshell River/ Delphia	5	54	34	<5	0
Musselshell River/ Mosby	<5	35	49	12	<5
Poplar River	0	6	6	14	64
Redwater River/Circle	0	<5	69	25	<5
Redwater River/Poplar	0	<5	46	32	9
Wolf Creek/Stamford	<5	30	51	15	0
Wolf Creek/Denton	<5	29	37	28	<5
Mean	7	32	26	15	15

Note: All other orders represented 5% of the total number of individuals collected at each station except the order Odonata, which comprised 11% of the community in the Redwater River at Poplar.

Table 45. Mean percent relative abundance of insects in the major macroinvertebrate orders -- Southeast Loop

Station	Plecoptera (stoneflies)	Ephemeroptera (mayflies)	Trichoptera (caddisflies)	Diptera (true flies)	Hemiptera (true bugs)
Armell's Creek	0	<5	29	36	< 5
Beaver Creek	5	28	39	17	< 5
Bighorn River	10	49	16	21	< 5
Clark's Fork River	14	55	14	16	0
Little Missouri River	0	35	17	42	< 5
Powder River/Broadus	25	36	31	< 5	0
Powder River/Locate	<5	75	21	0	0
Rosebud Creek	0	47	14	24	5
Shields River	32	39	23	6	0
Tongue River/ Brandenberg	18	53	23	<5	0
Tongue River/ Miles City	19	45	27	9	0
Yellowstone River/ Livingston	14	41	25	19	0
Yellowstone River/ Billings	20	40	5	31	0
Yellowstone River/ Huntley	19	54	12	15	<5
Yellowstone River/ Forsyth	0	45	16	38	<5
Yellowstone River/ Sidney	< 5	49	40	<5	7
Mean	12	44	22	18	5

Note: All other orders comprised less than 5% except 19% Amphipoda on Armell's Creek, 8% Megaloptera on Beaver Creek, and 8% Coleoptera on Rosebud Creek.

Table 46. Number of macroinvertebrate taxa collected — Northeast Loop

Station	Spring	Summer	Fall	Mean	Total
Beaver Creek/Hinsdale	*	10	8	9	12
Box Elder Creek	7	**	**	7	7
Big Muddy Creek	*	*	5	5	5
Big Spring Creek	15	14	12	14	20
Judith River/Utica	16	13	14	14	22
Judith River/Danvers	9	11	13	11	18
Judith River/Winifred	6	11	15	11	18
Milk River/Nashua	*	1	1	1	1
Missouri River/ Winifred	10	12	13	12	21
Missouri River/ Moberge	*	7	7	7	12
Missouri River/ Culbertson	*	0	0	0	0
Musselshell River/ Harlowton	14	17	16	16	27
Musselshell River/ Bundy	9	7	16	11	22
Musselshell River/ Delphia	9	12	11	11	17
Musselshell River/ Mosby	5	16	5	9	19
Poplar River	*	4	5	4	7
Redwater River/Circle	7	5	10	7	15
Redwater River/Poplar	*	9	5	7	9
Wolf Creek/Stamford	13	13	4	10	19
Wolf Creek/Denton	9	12	10	10	17
Mean	10	10	9	9	15

* Ice or flood conditions

** No Flow

Table 47. Number of macroinvertebrate taxa collected -- Southeast Loop

Station	Spring	Summer	Fall	Mean	Total
Armell's Creek	4	11	1	5	14
Beaver Creek/Wibaux	11	11	6	9	20
Bighorn River	14	15	17	15	26
Clark's Fork River	18	5	14	12	22
Little Missouri River	17	8	2	9	20
Powder River/Broadus	3	9	6	6	15
Powder River/Locate	*	2	5	4	6
Rosebud Creek	4	12	13	10	17
Shields River	15	11	16	14	25
Tongue River/ Brandenberg	12	8	14	11	19
Tongue River/ Miles City	4	13	11	9	21
Yellowstone River/ Livingston	17	18	19	18	25
Yellowstone River/ Billings	15	11	10	12	22
Yellowstone River/ Huntley	15	10	13	13	21
Yellowstone River/ Forsyth	3	13	13	10	20
Yellowstone River/ Sidney	*	9	5	7	9
Mean	11	10	10	10	19

*Flood Conditions

Table 48. Macroinvertebrate genus diversity -- Northeast Loop

Station	Spring	Summer	Fall	Mean
Beaver Creek/Hinsdale	*	2.47	2.22	2.35
Box Elder Creek	2.34	**	**	2.34
Big Muddy Creek	*	*	0.78	0.78
Big Spring Creek	3.26	3.17	2.99	3.14
Judith River/Utica	3.38	3.24	3.28	3.30
Judith River/Danvers	2.17	2.70	3.00	2.62
Judith River/Winifred	1.92	2.75	3.35	2.67
Milk River/Nashua	*	0	0	0
Missouri River Winifred	2.83	2.35	3.47	2.88
Missouri River Moberge	*	1.56	2.14	1.85
Missouri River/ Culbertson	*	0	0	0
Musselshell River/ Harlowton	2.96	3.05	3.18	3.06
Musselshell River/ Bundy	2.74	2.24	3.10	2.69
Musselshell River/ Delphia	2.85	2.51	3.04	2.80
Musselshell River/ Mosby	1.77	3.50	2.21	2.49
Poplar River	*	0.54	2.20	1.37
Redwater River/Circle	2.18	0.97	1.08	1.41
Redwater River/Poplar	*	1.37	2.02	1.70
Wolf Creek/Stanford	3.30	2.33	1.38	2.34
Wolf Creek/Denton	2.28	2.74	1.91	2.31
Mean	2.61	2.34	2.43	2.34

* ice or flood conditions

**no flow

Table 49. Macroinvertebrate genus diversity -- Southeast Loop

Station	Spring	Summer	Fall	Mean
Armell's Creek	0.75	2.21	0	0.99
Beaver Creek/Wibaux	2.90	2.16	1.61	2.22
Bighorn River	3.50	3.43	3.38	3.44
Clark's Fork River	3.16	1.64	3.34	2.71
Little Missouri River	3.39	2.16	0.29	1.95
Powder River/Broadus	1.15	1.45	1.46	1.35
Powder River/Locate	*	0.07	1.58	0.83
Rosebud Creek	0.05	2.74	2.97	1.92
Shields River	3.18	2.97	3.25	3.13
Tongue River/ Brandenberg	3.12	2.16	3.15	2.81
Tongue River/ Miles City	1.68	3.09	2.93	2.57
Yellowstone River/ Livingston	3.61	3.53	3.82	3.65
Yellowstone River/ Billings	3.31	2.14	3.10	2.85
Yellowstone River/ Huntley	2.97	2.62	3.23	2.94
Yellowstone River/ Forsyth	1.27	2.75	2.44	2.15
Yellowstone River/ Sidney	*	2.32	1.92	2.12
Mean	2.43	2.34	2.40	2.35

*flood conditions

Table 50. Number of macroinvertebrate individuals collected -- Northeast Loop

Station	Spring	Summer	Fall	Mean
Beaver Creek/Hinsdale	*	127	67	97
Box Elder Creek	18	**	**	18
Muddy Creek	*	*	40	40
Big Spring Creek	103	118	102	108
Judith River/Utica	95	96	114	102
Judith River/Danvers	72	94	75	80
Judith River/Winifred	50	181	123	118
Milk River/Nashua	*	34	58	46
Missouri River/Winifred	50	159	83	97
Missouri River/Mobridge	*	92	118	105
Missouri River/ Culbertson	*	0	0	0
Musselshell River/ Harlowton	114	119	100	111
Musselshell River/ Bundy	39	57	118	71
Musselshell River/ Delphia	30	126	115	90
Musselshell River/ Mosby	38	85	133	85
Poplar River	*	48	9	28
Redwater River/Circle	34	135	170	113
Redwater River/Poplar	*	101	18	60
Wolf Creek/Stamford	81	110	33	75
Wolf Creek/Denton	52	77	64	64
Mean	60	104	86	79

* ice or flood conditions

** no flow

Table 51. Number of macroinvertebrate individuals collected -- Southeast Loop

Station	Spring	Summer	Fall	Mean
Armell's Creek	63	62	4	43
Beaver Creek/Wibaux	64	75	66	68
Bighorn River	171	105	139	138
Clark's Fork River	126	77	98	100
Little Missouri River	94	123	20	79
Powder River/Broadus	7	96	39	47
Powder River/Locate	*	115	26	70
Rosebud Creek	39	108	64	70
Shields River	124	85	126	112
Tongue River/ Brandenberg	70	46	100	72
Tongue River/ Miles City	11	80	45	45
Yellowstone River/ Livingston	123	109	92	108
Yellowstone River/ Billings	115	90	37	81
Yellowstone River/ Huntley	104	107	91	101
Yellowstone River/ Forsyth	43	75	139	86
Yellowstone River/ Sidney	*	61	61	61
Mean	82	88	72	80

*Flood conditions



SUMMARY

This report presents data for 33 biologically-related water quality variables at 36 stations over three seasons. It may be instructive to consolidate this information so that stations in each loop can be compared at a glance. The resulting overview would put each stream's biological health in perspective by comparing it with that of other streams and stream reaches in the same geographical region of the state.

One such consolidation scheme incorporates mean values for the following key variables:

1. Specific conductance (micromhos @ 25 C)
2. Sodium adsorption ratio (summer only)
3. Total suspended sediment (mg/l)
4. Laboratory turbidity (NTU)
5. Total soluble inorganic nitrogen (mg/l)
6. Total phosphorus (mg/l)
7. Algal assay control mean maximum standing crop (mg/l) (summer only)
8. Chlorophyll a accural (mg/m²/day)
9. Biomass accrual (mg/m²/day)
10. Autotrophic index
11. Number of diatom species
12. Diatom species diversity ($\bar{d}$)
13. Number of macroinvertebrate taxa
14. Macroinvertebrate genus diversity ($\bar{d}$)
15. Number of macroinvertebrate organisms collected

In this scheme, the assumption is made that the least amount of algal nutrients and periphyton production is the most desirable case. Variables where the lowest value is presumed to reflect the best water quality are numbers 1-10 in the list above. Variables where the highest value is presumed to reflect the best water quality are numbers 11-15.

All mean values are listed in order from highest to lowest (or lowest to highest in the case of variables 11-15) for each variable. The station in each loop with the extreme (highest or lowest) value indicating the poorest water quality is given a rank of one for that variable. The station with the second highest or lowest value indicating the second poorest water quality is then given a rank of two, and so on until all of the stations in each loop have been ranked for that variable.

When all 20 stations in the Northeast Loop and all 16 stations in the Southeast Loop have been ranked for each of the 15 variables, ranks for each station are totaled and divided by the number of variables measured at that station. The resulting composite rank may be used to assess relative biological health among the stations in each loop.

Composite rankings, arranged in order from the highest (best quality) to the lowest (worst quality) are presented in Table 52 for the Northeast Loop and Table 53 for the Southeast Loop.

Table 52. Composite ranking of stations in the Northeast Loop.
Best possible rank = 20; worst possible rank = 1.

Station	Rank
Musselshell River/Harlowton	14.2
Judith River/Utica	13.0
Missouri River/Mobridge	12.9
Wolf Creek/Stanford	12.7
Redwater River/Circle	12.5
Missouri River/Winifred	11.9
Big Spring Creek	11.5
Musselshell River/Bundy	10.9
Beaver Creek/Hinsdale	10.6
Judith River/Danvers	9.9
Missouri River/Oulbertson	9.5
Judith River/Winifred	9.4
Poplar River	9.4
Musselshell River/Delphia	9.3
Big Muddy Creek	8.3
Wolf Creek/Denton	8.2
Musselshell River/Mosby	7.7
Box Elder Creek	7.6
Milk River/Nashua	7.0
Redwater River/Poplar	6.5

Table 53. Composite ranking of stations in the Southeast Loop.
Best possible rank = 16; worst possible rank = 1.

Station	Rank
Yellowstone River/Livingston	12.6
Shields River	10.2
Bighorn River	9.4
Yellowstone River/Forsyth	9.3
Tongue River/Brandenberg	9.3
Beaver Creek/Wibaux	8.9
Yellowstone River/Billings	8.4
Little Missouri River	8.3
Yellowstone River/Huntley	8.3
Yellowstone River/Sidney	8.0
Rosebud Creek	7.9
Tongue River/Miles City	7.3
Armell's Creek	6.9
Powder River/Locate	6.6
Clark's Fork River	6.5
Powder River/Broadus	5.7



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APPENDIXES

Appendix A. Streams and stations in the Montana biological monitoring network

SOUTHWEST LOOP (Report completed in February 1979)

Beaverhead River at Twin Bridges
Big Hole River near Twin Bridges
Boulder River below Boulder
Clark Fork River at Deer Lodge
East Gallatin River near Belgrade
Grasshopper Creek near mouth near Dillon
Jefferson River near Three Forks
Madison River near Three Forks
Muddy Creek at mouth near Dell
Prickly Pear Creek at East Helena
Prickly Pear Creek near mouth
Red Rock River above Lima Reservoir
Ruby River near Twin Bridges
Sheep Creek above Muddy Creek
Silver Bow Creek below Warm Springs Ponds
West Fork Madison River near mouth
West Gallatin River at Central Park (190)

NORTHCENTRAL LOOP (Report completed in March 1979)

Big Sandy Creek near mouth
Dearborn River near mouth
Lodge Creek near Chinook
Marias River near Shelby
Marias River at Loma
Milk River at Havre
Milk River above Chinook
Missouri River at Cascade
Missouri River at Fort Benton
Muddy Creek near mouth at Vaughn
Pondera Creek near mouth near Chester
Smith river near Ulm
Sun River near Fort Shaw
Sun River below Vaughn
Teton River near Dutton
Teton River near Fort Benton

NORTHWEST LOOP (Report completed in November 1979)

Bitterroot River near mouth
Clark Fork River below Bonner Dam
Clark Fork River at Huson RR Bridge

Appendix A. (Continued)

NORTHWEST LOOP (Continued)

Clearwater River near mouth
Fisher River at mouth
Flathead River near Kalispell
Flathead River near mouth
Lake Creek near mouth near Troy
Little Blackfoot River at Avon
Middle Fork Flathead River near mouth
North Fork Flathead River near mouth
Stillwater River near mouth at Kalispell
Swan River near mouth
Swiftcurrent Creek near Babb
Whitefish River near mouth near Kalispell
Yaak River near mouth

NORTHEAST LOOP (Report completed in 1981)

Beaver Creek near Hinsdale at Beaverton
Box Elder Creek near Winnett
Big Muddy Creek near mouth near Culbertson
Big Spring Creek below Lewistown
Judith River near Utica
Judith River near Danvers
Judith River near mouth
Milk River at Nashua
Missouri River below Judith River
Missouri River at Fred Robinson Bridge
Missouri River at Culbertson
Musselshell River at Harlowton
Musselshell River above Roundup at Bundy
Musselshell River below Roundup at Delphia
Musselshell River at Mosby
Poplar River at mouth at Poplar
Redwater River at Circle
Redwater River near mouth
Wolf Creek at Stanford
Wolf Creek at Denton

SOUTHEAST LOOP (Report completed in 1981)

Armell's Creek (East Fork) near Colstrip
Beaver Creek at Wibaux
Bighorn River at Bighorn
Clark's Fork River near Laurel at Edgar
Little Missouri River at Capitol
Powder River at Broadus
Powder River near Miles City at Locate
Rosebud Creek near Colstrip

Appendix A. (Continued)

SOUTHEAST LOOP (Continued)

Shields River near mouth
Tongue River at Brandenburg
Tongue River at Miles City
Yellowstone River near Livingston
Yellowstone River at Billings (USGS Station)
Yellowstone River near Huntley
Yellowstone River at Forsyth
Yellowstone River near Sidney

Appendix B. Phosphate (PO₄ as P in mg/l) -- Northeast Loop

Station	Spring	Summer	Fall	Mean*
Beaver Creek/Hinsdale	0.300	0.053	0.011	0.121
Box Elder Creek	0.160	DRY	0.005	0.082
Big Muddy Creek	0.150	0.061	0.022	0.078
Big Spring Creek	0.058	0.058	0.003	0.040
Judith River/Utica	< 0.001	0.001	< 0.001	< 0.001
Judith River/Danvers	0.170	0.029	0.018	0.072
Judith River/Winifred	0.300	0.049	0.005	0.118
Milk River/Nashua	0.350	0.079	0.021	0.150
Missouri River/Winifred	0.240	0.032	0.022	0.098
Missouri River/Mobridge	0.240	0.032	0.006	0.093
Missouri River/ Culbertson	ICE	0.110	0.028	0.069
Musselshell River/ Harlowton	0.017	0.008	< 0.001	0.008
Musselshell River/ Bundy	0.260	0.015	0.001	0.092
Musselshell River/ Delphia	0.310	0.030	< 0.001	0.113
Musselshell River/ Mosby	0.440	0.037	0.003	0.160
Poplar River	0.160	0.033	0.005	0.066
Redwater River/Circle	0.070	0.012	0.005	0.029
Redwater River/Poplar	0.330	0.011	< 0.001	0.114
Wolf Creek/Stanford	0.006	0.006	0.005	0.006
Wolf Creek/Denton	0.020	0.001	0.005	0.009
Mean*	0.188	0.034	0.008	0.076

Assumes concentrations less than 0.001 mg/l equal zero.

Appendix C. Phosphate (PO_4 as P in mg/l) -- Southeast Loop

Station	Spring	Summer	Fall	Mean*
Arnell's Creek	0.047	0.008	DFY	0.028
Beaver Creek/Wibaux	0.120	0.006	< 0.001	0.042
Bighorn River	0.150	0.033	0.002	0.062
Clark's Fork River	0.280	0.480	0.005	0.255
Little Missouri River	0.270	0.018	0.006	0.098
Powder River/Broadus	2.500	0.380	0.025	0.968
Powder River/Locate	1.800	0.310	0.010	0.707
Rosebud Creek	0.180	0.110	0.008	0.099
Shields River	0.084	0.053	<0.001	0.046
Tongue River/ Brandenberg	0.150	0.019	0.005	0.058
Tongue River/ Miles City	0.450	0.022	<0.001	0.157
Yellowstone River/ Livingston	0.020	0.031	0.002	0.018
Yellowstone River/ Billings	0.100	0.110	0.013	0.074
Yellowstone River/ Huntley	0.120	0.063	0.020	0.068
Yellowstone River/ Forsyth	0.270	0.075	0.028	0.124
Yellowstone River/ Sidney	0.290	0.049	0.010	0.116
Mean*	0.427	0.110	0.009	0.186

*Assumes concentrations less than 0.001 mg/l equal zero

Appendix D. Total phosphorus (P in mg/l) -- Northeast Loop

Station	Spring	Summer	Fall	Mean*
Beaver Creek/Hinsdale	0.47	0.13	0.02	0.21
Box Elder Creek	0.21	DRY	0.02	0.12
Big Muddy Creek	0.27	0.18	0.14	0.20
Big Spring Creek	0.11	0.09	0.04	0.08
Judith River/Utica	<0.01	< 0.01	<0.01	< 0.01
Judith River/Danvers	0.22	0.06	0.03	0.10
Judith River/Winifred	0.35	0.08	0.02	0.15
Milk River/Nashua	0.64	0.17	0.06	0.29
Missouri River/ Winifred	0.30	0.06	0.04	0.13
Missouri River/ Mabridge	0.28	0.07	0.01	0.12
Missouri River/ Culbertson	ICE	0.16	0.02	0.09
Musselshell River/ Harlowton	0.04	0.03	<0.01	0.02
Musselshell River/ Bundy	0.31	0.17	<0.01	0.16
Musselshell River/ Delphia	0.38	0.15	<0.01	0.18
Musselshell River/ Mosby	0.51	0.09	<0.01	0.20
Poplar River	0.32	0.12	<0.01	0.15
Redwater River/Circle	0.13	0.04	0.01	0.06
Redwater River/Poplar	0.46	---	<0.01	0.23
Wolf Creek/Stanford	0.03	0.02	0.02	0.02
Wolf Creek/Denton	0.06	0.04	0.02	0.04
Mean*	0.27	0.09	0.02	0.12

*Assumes concentrations less than 0.01 mg/l equal zero

Appendix E. Total phosphorus (P in mg/l) -- Southeast Loop

Station	Spring	Summer	Fall	Mean*
Armell's Creek	0.07	0.04	DRY	0.06
Beaver Creek/Wibaux	0.17	0.04	0.01	0.07
Bighorn River	0.20	0.06	0.01	0.09
Clark's Fork River	0.35	0.68	0.02	0.35
Little Missouri River	0.40	0.06	0.02	0.16
Powder River/Broadus	3.7	0.60	0.04	1.45
Powder River/Locate	2.6	0.49	0.02	1.04
Rosebud Creek	0.25	0.20	0.02	0.16
Shields River	0.13	0.07	< 0.01	0.07
Tongue River/ Brandenberg	0.25	0.07	< 0.01	0.11
Tongue River/ Miles City	0.58	0.05	< 0.01	0.21
Yellowstone River/ Livingston	0.03	0.04	0.01	0.03
Yellowstone River/ Billings	0.14	0.17	0.03	0.11
Yellowstone River/ Huntley	0.17	0.07	0.03	0.09
Yellowstone River/ Forsyth	0.35	0.10	0.03	0.16
Yellowstone River/ Sidney	0.38	0.09	0.02	0.16
Mean*	0.61	0.18	0.02	0.27

*Assumes concentrations less than 0.01 mg/l equal zero

Appendix F. Nitrate plus nitrite ($\text{NO}_3 + \text{NO}_2$ as N in mg/l) -- Northeast Loop

Station	Spring	Summer	Fall	Mean*
Beaver Creek/Hinsdale	0.10	< 0.01	< 0.01	0.03
Box Elder Creek	0.07	DRY	< 0.01	0.04
Big Muddy Creek	0.31	< 0.01	< 0.01	0.10
Big Spring Creek	0.86	0.55	0.71	0.71
Judith River/Utica	0.05	0.02	0.06	0.04
Judith River/Danvers	1.30	0.90	1.60	1.27
Judith River/Winifred	1.40	0.60	0.94	0.98
Milk River/Nashua	0.24	< 0.01	< 0.01	0.08
Missouri River/ Winifred	1.40	< 0.01	0.25	0.55
Missouri River/ Moberg	0.41	< 0.01	< 0.01	0.14
Missouri River/ Culbertson	ICE	0.15	0.16	0.16
Musselshell River/ Harlowton	< 0.01	< 0.01	0.01	< 0.01
Musselshell River/ Bundy	0.30	< 0.01	< 0.01	0.10
Musselshell River/ Delphia	0.29	< 0.01	< 0.01	0.10
Musselshell River/ Mosby	0.22	< 0.01	< 0.01	0.07
Poplar River	0.25	< 0.01	< 0.01	0.08
Redwater River/Circle	0.29	< 0.01	< 0.01	0.10
Redwater River/Poplar	0.36	< 0.01	< 0.01	0.12
Wolf Creek/Stamford	0.16	0.11	0.37	0.21
Wolf Creek/Denton	2.10	4.90	0.72	2.57
Mean*	0.53	0.38	0.24	0.38

*Assumes concentrations less than 0.01 mg/l equal zero

Appendix G. Nitrate plus nitrite ($\text{NO}_3 + \text{NO}_2$ as N in mg/l) -- Southeast Loop

Station	Spring	Summer	Fall	Mean*
Armell's Creek	0.37	< 0.01	DRY	0.18
Beaver Creek/Wibaux	0.61	< 0.01	< 0.01	0.20
Bighorn River	0.29	0.18	0.16	0.21
Clark's Fork River	0.52	0.24	0.83	0.53
Little Missouri River	0.19	< 0.01	< 0.01	0.06
Powder River/Broadus	0.43	0.32	< 0.01	0.25
Powder River/Locate	0.30	< 0.01	< 0.01	0.10
Rosebud Creek	0.24	0.08	< 0.01	0.11
Shields River	0.40	0.32	0.27	0.33
Tongue River/ Brandenberg	0.29	0.01	< 0.01	0.10
Tongue River/ Miles City	0.18	0.02	0.08	0.09
Yellowstone River/ Livingston	0.18	0.03	0.05	0.09
Yellowstone River/ Billings	0.49	0.12	0.10	0.20
Yellowstone River/ Huntley	0.46	0.07	0.20	0.24
Yellowstone River/ Forsyth	0.38	0.16	0.10	0.21
Yellowstone River/ Sidney	0.26	< 0.01	0.06	0.11
Mean*	0.35	0.10	0.12	0.19

*Assumes concentrations less than 0.01 mg/l equal zero

Appendix H. Total ammonia (NH_4^+ + NH_3 as N in mg/l) -- Northeast Loop

Station	Spring	Summer	Fall	Mean*
Beaver Creek/Hinsdale	0.03	< 0.01	0.02	0.02
Box Elder Creek	0.06	DRY	0.04	0.05
Big Muddy Creek	0.02	0.03	0.03	0.03
Big Spring Creek	0.05	0.04	0.02	0.04
Judith River/Utica	<0.01	< 0.01	0.02	< 0.01
Judith River/Danvers	0.05	0.01	0.02	0.03
Judith River/Winifred	0.05	0.01	0.01	0.02
Milk River/Nashua	0.02	< 0.01	<0.01	<0.01
Missouri River/Winifred	0.04	< 0.01	0.02	0.02
Missouri River/Mobridge	<0.01	< 0.01	<0.01	<0.01
Missouri River/ Culbertson	ICE	0.01	0.01	0.01
Musselshell River/ Harlowton	<0.01	< 0.01	0.01	<0.01
Musselshell River/ Bundy	0.06	< 0.01	0.01	0.02
Musselshell River/ Delphia	0.07	< 0.01	0.01	0.03
Musselshell River/ Mosby	0.07	<0.01	0.01	0.03
Poplar River	0.01	0.01	< 0.01	<0.01
Redwater River/Circle	0.16	0.01	< 0.01	0.06
Redwater River/Poplar	0.15	< 0.01	< 0.01	0.05
Wolf Creek/Stanford	<0.01	0.02	0.02	0.01
Wolf Creek/Denton	<0.01	0.03	0.03	0.02
Mean*	0.04	0.01	0.01	0.02

*Assumes concentrations less than 0.01 mg/l equal zero

Appendix I. Total ammonia (NH_4^+ + NH_3 as N in mg/l) -- Southeast Loop

Station	Spring	Summer	Fall	Mean*
Armell's Creek	0.57	0.05	DRY	0.31
Beaver Creek/Wibaux	0.13	< 0.01	< 0.01	0.04
Bighorn River	0.05	< 0.01	< 0.01	0.02
Clark's Fork River	0.05	< 0.01	< 0.01	0.02
Little Missouri River	0.03	< 0.01	0.01	0.01
Powder River/Broadus	0.19	0.01	< 0.01	0.07
Powder River/Locate	0.15	0.11	0.02	0.09
Rosebud Creek	0.30	0.01	0.02	0.11
Shields River	0.05	< 0.01	< 0.01	0.02
Tongue River/ Brandenberg	0.05	< 0.01	< 0.01	0.02
Tongue River/ Miles City	0.06	< 0.01	< 0.01	0.02
Yellowstone River/ Livingston	< 0.01	< 0.01	< 0.01	< 0.01
Yellowstone River/ Billings	0.18	0.04	0.46	0.23
Yellowstone River/ Huntley	0.10	< 0.01	0.02	0.04
Yellowstone River/ Forsyth	0.10	0.09	0.01	0.07
Yellowstone River/ Sidney	0.02	0.01	< 0.01	0.01
Mean*	0.13	0.02	0.04	0.06

*Assumes concentrations less than 0.01 mg/l equal zero

Appendix J. Kjeldahl nitrogen (N in mg/l) -- Northeast Loop

Station	Spring	Summer	Fall	Mean*
Beaver Creek/Hinsdale	1.30	1.30	0.75	1.12
Box Elder Creek	0.72	DRY	0.82	0.77
Big Muddy Creek	1.40	1.60	2.40	1.80
Big Spring Creek	0.37	0.44	0.30	0.37
Judith River/Utica	0.09	0.21	0.07	0.12
Judith River/Danvers	0.82	0.47	0.43	0.57
Judith River/Winifred	1.00	0.67	0.25	0.64
Milk River/Nashua	1.90	0.84	0.65	1.13
Missouri River/Winifred	0.80	0.35	0.39	0.51
Missouri River/Mobridge	0.61	0.45	0.28	0.45
Missouri River/ Culbertson	ICE	0.42	0.23	0.32
Musselshell River/ Harlowton	0.45	0.30	0.07	0.27
Musselshell River/ Bundy	0.89	0.63	0.23	0.58
Musselshell River/ Delphia	1.30	0.49	0.28	0.69
Musselshell River/ Mosby	1.10	0.60	0.28	0.66
Poplar River	1.50	1.20	0.45	1.05
Redwater River/Circle	0.77	0.75	0.35	0.62
Redwater River/Poplar	1.80	0.90	0.42	1.04
Wolf Creek/Stanford	0.17	0.52	0.41	0.37
Wolf Creek/Denton	0.75	0.99	0.84	0.86
Mean*	0.93	0.69	0.50	0.70

*Assumes concentrations less than 0.05 mg/l equal zero

Appendix K. Kjeldahl nitrogen (N in mg/l) -- Southeast Loop

Station	Spring	Summer	Fall	Mean*
Armell's Creek	1.10	0.91	DRY	1.00
Beaver Creek/Wibaux	0.88	---	0.33	0.60
Bighorn River	0.60	0.64	0.30	0.51
Clark's Fork River	0.86	1.20	0.30	0.79
Little Missouri River	1.10	0.75	0.43	0.76
Powder River/Broadus	6.60	2.00	0.49	3.03
Powder River/Locate	5.10	0.84	0.35	2.10
Rosebud Creek	1.20	0.91	0.45	0.85
Shields River	0.62	0.25	0.15	0.34
Tongue River/ Brandenberg	0.71	0.35	0.24	0.43
Tongue River/ Miles City	1.20	2.20	0.34	1.25
Yellowstone River/ Livingston	0.25	0.10	0.23	0.19
Yellowstone River/ Billings	0.63	0.50	0.76	0.63
Yellowstone River/ Huntley	0.61	0.20	0.32	0.38
Yellowstone River/ Forsyth	0.89	0.26	0.30	0.48
Yellowstone River/ Sidney	0.88	0.32	0.35	0.52
Mean*	1.45	0.76	0.36	0.87

*Assumes concentrations less than 0.05 mg/l equal zero

---Sample exceeded holding time





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